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ABSTRACT

This publication is the third work in the UNESCO series "The Teaching of Basic Sciences," and is based on the proceedings of the international conference on "The Education of Teachers for Integrated Science." The views of all the working groups of the conference, together with edited texts of the papers presented, form the text of this volume, to which is added an extensive bibliography of relevant books and articles prepared for the use of conference members. The document is arranged in four parts. The first section looks at general questions relating to teacher education for integrated science, the second at particular issues of pre-service and in-service education, the third at ways of improving science teaching programs and evaluating results and the fourth raises questions about the relationship of science and science teacher education to wider issues in society. Each section ends with a commentary on the discussions following the presentation of papers and the findings of the working groups. (Author/EB)

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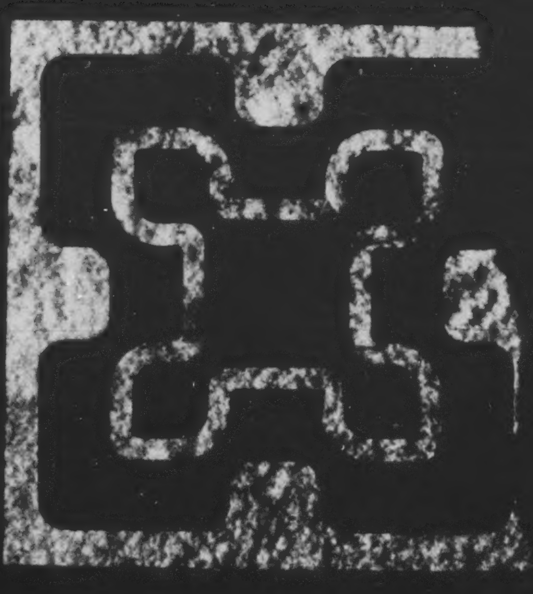

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New trends in integrated science teaching. Prepared by P. E. Richmond, Senior Lecturer in Education, University of Southampton (United Kingdom).
Vol. I: 1971
Vol. II: 1973

New trends in integrated science teaching: Education of teachers

Volume III

Edited by
P.E. Richmond
Senior Lecturer in Education
University of Southampton
United Kingdom

Based on the proceedings
of the ICSU Conference
"The Education of Teachers
for Integrated Science –
Teaching Science for
Today's Society" held at the
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PREFACE

The present publication is the third work on the subject of integrated science teaching in the Unesco series "The teaching of basic sciences". The two previous volumes attempted to exemplify and analyse trends; this volume is based on the proceedings of the international conference on "The Education of Teachers for Integrated Science" organized by the ICSU Committee on the Teaching of Science, with Unesco support, at the University of Maryland, U.S.A., in April 1973.

An earlier conference organized in Varna, Bulgaria, with Unesco support, by the Inter-Union Commission on Science Teaching had studied integrated science teaching projects then under development, and attempted to answer the questions "what is integrated science teaching?" and "why teach integrated science?". Subsequently, in 1969, it became apparent to Unesco and to the newly-constituted ICSU Committee on the Teaching of Science that if integrated science courses were to be widely implemented, teachers needed to be educated in their methods and content. It was therefore decided to organize the above-mentioned conference at the University of Maryland to review major issues in the education of teachers for integrated science, and to disseminate the conclusions widely.

The views of all the working groups of the Conference, together with edited texts of the papers presented, form the text of this volume, to which is added an extensive bibliography of relevant books and articles prepared at the Science Teaching Centre of the University of Maryland for the use of conference members.

The papers and working group reports have been arranged in four sections. The first section looks at general questions relating to teacher education for integrated science, the second at particular issues of pre-service and in-service education, the third at ways of improving science teaching programmes and evaluating results, and the fourth raises questions about the relationship of science and science teacher education to wider issues in society. Each section ends with a commentary on the discussions following the presentation of papers and the findings of the working groups.

The matters raised in this volume often demand consideration of fundamental questions of education. What is schooling for? What is science? What is education? How can we best educate teachers? How do we know what we have achieved? One of the strengths of integrated science teaching is that it ensures that teachers and teacher educators look afresh at such issues and are not content merely to rewrite syllabuses in terms of subject matter. The pupil, scientific processes, and social awareness are acknowledged as central factors in the design of teaching schemes.

The Maryland Conference was intended to stimulate thought but, more than this, it was intended to provoke activity at a number of levels, at national and local conferences and workshops, in colleges and in schools. The contributors had widely-varying backgrounds and the questions raised at the Conference and the tentative solutions offered may not be universally applicable. It is expected, however, that they will be of use in sensitizing all those who are working with teachers to the educational possibilities opened up by the introduction of integrated science and that they may lead to improved practices in the education of science teachers.

Educational research workers interested in integrated science teaching will also find many urgent questions in this volume to which they may wish to address themselves. There is much scope for both research and development work in relation to these questions.

Appreciation is expressed to all those who contributed to the success of the conference and, in particular, to all contributors to this volume who generously gave of their time and energy and, in some cases, allowed the use of copyright material. Unesco and the ICSU Committee on the Teaching of Science also acknowledge with appreciation the devoted work of the Editor, Mr. P. E. Richmond of the University of Southampton, United Kingdom.

The views expressed are the responsibility of the editor and the authors and do not necessarily reflect the views of Unesco or ICSU.

A Report of the Conference has already been published by ICSU. It includes names and addresses of participants and a list of papers submitted. Copies can be obtained from Mr. D.G. Chisman, British Council (Education and Science Division), Tavistock House South, Tavistock Square, London WCIH 9LL. Price $1.25 or 50p.

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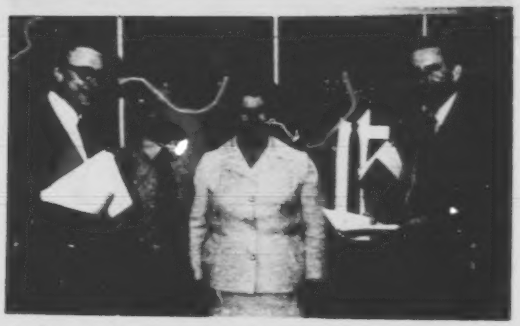
Part 1

Integrated Science and the Science Teacher



1. Some Members of the Organizing Committee. Left to right: Charles Taylor, Peter Richmond, Marjorie Gardner, Al. Baez, Dave Lockard.

2. The Local Arrangements Committee at a Breakfast Meeting. The Conference Secretary, Mr. D. G. Chisman outlines his plans.

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Plate 1. The International Conference 'The Education of Teachers for Integrated Science – Teaching Science for Today's Society' held at the University of Maryland 3-13 April 1973.
(Photos: Melton Golman)

THE EDUCATION OF TEACHERS OF INTEGRATED SCIENCE: SOME BASIC QUESTIONS AND PROPOSED ANSWERS

Harold A. Foecke
Director, Division of Pre-University Science and Technology Education, UNESCO, Paris.

1. Introduction

Because this is the first presentation at the first substantive session of this Conference, my principal responsibility is to present an overall framework which will provide a meaningful place for, and shed some light upon the interactions among, the various more specialized sessions which will follow. This I will try to do by posing some questions which I believe are basic and by proposing some answers which I believe are sound. I shall concentrate on three general questions: (a) what do we mean by integrated science, (b) how would we design programmes for the education of teachers, and (c) what special opportunities and problems exist in the training of teachers of integrated science? There are some links between these questions which I shall illustrate as we proceed.

2. What is Integrated Science?

In the past, many who have considered this question, which is obviously a pivotal concern for this Conference as a whole, have concentrated on the adjective 'integrated'. Whatever I might have wanted to say along such lines could readily be summarized by a remark of Dr. Baez, namely, that integrated science is 'non-disintegrated science'; it is seeing nature in the unity with which it sees itself. The 'disintegration' is only apparent and not real; it is of human origin – a product of the manner and the sequence in which man has pushed back the frontiers of knowledge. Debates about 'levels' and 'modes' of integration, important though they be, can be regarded largely as efforts to counteract the undesirable consequences of inevitable specialization.

What I think is of at least equal importance, and what I find discussed less often, is the meaning of the noun 'science'. Do we intend to include the 'social sciences'? Or the 'applied sciences' (whatever they are), and are these latter distinct from 'technology'? The most casual analysis of current literature reveals that even those who call themselves 'scientists' (not to mention the man in the street) use the term 'science' in ways that are frequently ambiguous, sometimes incompatible, and occasionally contradictory. Furthermore, this same lack of precision is found among science educators. In fact, in Volume II of 'New Trends in Integrated Science Teaching' several chapters are devoted to analysing the different kinds of content in the various programmes that consider themselves to be some form of integrated science. When one looks at these chapters, one finds some very heterogeneous items all going under the label 'science'. This finding, in itself, isn't harmful. However, I believe that we could better understand and relate existing programmes, and could more effectively design future ones, if we could agree: (a) that 'science' and 'technology' are related but different, (b) that students should be exposed to both, and (c) that we probably should strive to have educational programmes which present *science and technology* in an integrated manner.

3. How Do 'Science' and 'Technology' Differ?

To assert that 'science' and 'technology' are 'related but different' could appear to be merely a matter of definition, a game of words. However, my concern is not with the words themselves but with the ideas which lie behind them. Therefore, stated in a more basic way, I feel that there are two areas of human activity which, while related, are fundamentally different and that it is therefore important that society find separate words to characterize these. Briefly, these two areas of human activity are: (a) the effort associated with man's natural desire to know, to understand, to explain, to predict, etc., and (b) the result of man's equally natural desire to find ever new and better ways of satisfying his needs, of achieving his goals, of doing the job he wants done. I have tried to illustrate and to summarize the contrasts between these areas of human activity on Figure 1, which shows, for each, the 'motive force' which causes the activity, the 'process' which characterizes it, and the 'product' thereof.

Contrasting the 'motive forces', one is essentially a desire 'to know', the other a desire 'to do', which I hope you will agree are different in nature. But, they can be related (and here is where some of the confusion arises) because, sometimes, in order 'to do' something better it is necessary 'to know' something more. But this merely means that the product of one activity becomes an input for the other; the activities themselves remain distinct.

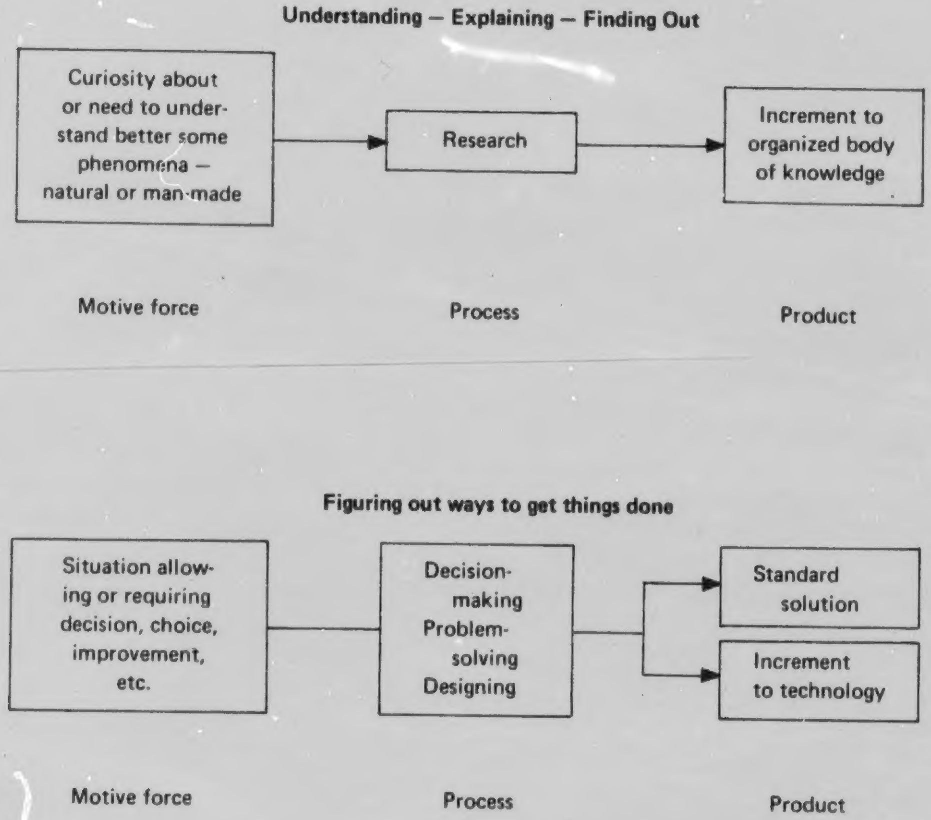
Understanding – Explaining – Finding Out
Curiosity about or need to understand better some phenomena – natural or man-made
Research
Increment to organized body of knowledge
Motive force
Process
Product
Figuring out ways to get things done
Situation allowing or requiring decision, choice, improvement, etc.
Decision-making Problem-solving Designing
Standard solution
Increment to technology
Motive force
Process
Product

Figure 1

Turning now to the 'process', I have used the term 'research' to characterize the activity of seeking knowledge and understanding, and I run the risk of getting involved in another semantic problem because the word 'research' is also currently used in many ways. I am tempted to say that the process I have in mind is the application of the 'scientific method' to particular phenomena which are not understood, but that doesn't help too much because there are so many versions of the scientific method in the literature. Trying to get behind the terminology, I restrict the term 'research' to organized attempts to explain and to find cause-and-effect relationships among phenomena, the specific features of these 'organized attempts' differing somewhat according to the nature of the phenomena involved (biological, astronomical, chemical, anthropological, geological, etc.). In my meaning of 'research', I do not include data collection *as such* (no matter how cleverly or skilfully it may be done); data collection is frequently one of the necessary steps in the process of research but it is not the essence thereof. The essence is more in that unpredictable leap of the intellect which finds (postulates for subsequent testing with the data of reality) meanings and relationships which were previously unknown. Similarly, I exclude from the meaning of 'research' the process of 'designing' or 'problem-solving' which characterizes the second area of human activity that I am talking about.

Turning therefore to this second area, as you see from Figure 1, I have used various words to characterize this second process. If I were to be asked to select a single phrase to embody the distinctions between this and the 'scientific method', I would call it the 'design method'. Apart from the words, it is the process by which an engineer decides how to improve the transportation system of a city, or a physician decides what to prescribe to cure a particular patient, or a lawyer decides how a particular client should plead before the courts, or an educator decides what programme of learning experiences would be best for a particular student (or group of students), or a minister decides how to bring spiritual comfort to a member of his congregation. This second process differs from the first as analysis differs from synthesis. The first proceeds from the particular to the general, trying to discover ever broader relationships to explain individual phenomena; the second moves in the opposite direction, bringing general principles to bear on specific problems. The first process asks *what is* (is there a relationship between smoking and lung cancer, what is the effect of various nutrients on plant growth, can concepts of set theory be learned by typical eight-year old children); the second process asks *what should be* (given my age, my health, my psychological make-up, should I smoke and, if so, what and how much; considering cost, availability, and all other factors, what fertilizer should I use on these crops this year; considering their previous education, their needs, and the other things they might learn, should I teach set theory to these eight-year old children). The distinction between these two processes is very important, and I wish that I could spend more time on it; I hope I have said enough to open up this question for you if you have not previously considered it.

Passing now to the contrast between the 'products' of these two processes, in the first case the result is an increment to the total reservoir of human understanding, to our 'organized body of knowledge' – which you will recognize is one of the many meanings of the term 'science'.

In fact, this is the sense in which I am using the word science in this presentation – the *organized* body of knowledge, resulting from a process of research (the 'scientific method'), which allows man to understand, explain, and predict phenomena both natural and man-made. This parenthetical expression 'natural and man-made' is important because it allows me to suggest my answer to the question I posed earlier concerning the nature of the so-called 'applied sciences' and of their relation to 'technology'. For me, the applied sciences are true sciences – in that they are organized bodies of knowledge which are expanded through research. However, in contrast with the natural sciences (concerned with understanding nature and natural phenomena), the applied sciences are concerned with the theoretical characteristics, behaviour, and properties of man-made (or 'man-modified') devices, systems, materials, processes, etc. Throughout history, human ingenuity in finding ways to get jobs done has regularly outstripped human understanding of the fundamental processes at work; the Romans built aqueducts without the knowledge of fluid mechanics which we now have, internal combustion engines were used for decades before the mechanisms of spark ignition were understood, electronic devices employing ionized gases were used successfully before the properties of plasmas were known, many drugs and medical practices work for unknown reasons (from aspirins to organ transplants), and we succeed in promoting student learning in the absence of a lot that we'd like to know about the process. 'Applied research' attempts to shed light on puzzling man-made phenomena, and the products are contributions to one or more of the applied sciences – engineering science, medical science, management science, agricultural science, educational science, etc. Please note that 'medical science' should not be confused with the practice of medicine, 'engineering science' with the practice of engineering, etc.; these are true sciences (i.e., organized bodies of knowledge) upon which, among other things, the professional practitioner must draw in deciding upon the course of action to be recommended in each case with which he must cope.

Turning now to the product of the second process, as shown in Figure 1, I suggest that there are two types of products. In most cases, the optimum solution to the problem being solved involves nothing essentially new; it is merely some variation of a standard or prototype solution. If the best solution to the problem of transporting materials across a river is the design of a suspension bridge (rather than some other type of bridge, or rather than a tunnel, or a ferry, etc.), the bridge will differ from other suspension bridges only in details of width, length, load capacity, etc.; there is no creativity involved and the designer merely draws upon the reservoir of existing possible solutions to find the best one.

However, this reservoir of possible solutions is built up by those occasional instances when, in an act of true creativity, the designer conceives of something (material, device, system, process, etc.) which never existed before – a free-piston engine, an electronic amplifier, pre-stressed concrete structures, synthetic materials, etc. Once it has been demonstrated that a new technique or device is useful in getting a job done, this new development becomes an increment to the reservoir of technology upon which future designers can draw in solving problems of a similar nature. So, from that point of view, 'technology' is the reservoir of techniques, processes, devices, materials, etc. which have demonstrated their usefulness in getting particular tasks accomplished, and this reservoir is built up by human ingenuity and creativity which is constantly finding new and better ways of doing things. Naturally, one finds in the literature many broad categories of technology (engineering technology, medical technology, educational technology, etc.), as well as highly specialized technologies (vacuum-forming technology, zone-refining technology, etc.).

Summarizing this section, I have tried to indicate the difference between 'science' and 'technology' by connecting these terms to two areas of human activity which, while related, differ fundamentally in terms of their products, processes, and motive forces. *Science* is the organized body of knowledge which attempts to explain phenomena (natural and man-made), the product of a process of research, a process which springs from a desire and/or need to know. *Technology* is the reservoir of techniques, materials, devices, etc. which have demonstrated usefulness in achieving various tasks, the reservoir being built up through creative instances of design (or problem-solving), a process which flows from man's desire to improve his lot, to find ever new and/or better ways of satisfying his needs.

4. What are the Educational Consequences of These Differences?

I stated earlier that I believed that students should be 'exposed' to both science and technology. Perhaps the reason for this feeling is now self-evident. We have rightly argued in the past that no citizens of today or tomorrow could be considered well educated without understanding science – by which I think we meant an understanding both of some of the more fundamental laws of nature and also of the process of scientific inquiry (its essence as well as its limitations). But, we are increasingly obliged to cope not only with nature but also with the man-made world; we must learn how to come to terms with this man-made world, to allow it to enrich our lives without enslaving us. Consequently, to some appropriate degree, all citizens of today and tomorrow should be helped to understand the design (or problem-solving) process, along with an appreciation of the characteristics of some of the more notable products of human ingenuity.

Indeed, the argument doesn't stop there. In terms of the two processes to be understood, it seems to me that the problem-solving or decision-making process is of much more direct importance to the average citizen. Although the man in the street would not often be personally involved in pushing back the frontiers of knowledge through research, almost everyone is involved in decision-making, in deciding what to do when confronted with new or changing conditions or circumstances. In a world in which change is going to be an ever more prevalent condition, what could be more important, what could better prevent 'future shock', than helping students learn the process of intelligent decision-making?

A very important recent publication, *Learning to Be,* the report, of a Unesco-appointed International Commission on the Development of Education, a publication with which some of you are already familiar, deals in part with the teaching of technology, and the teaching of it in relation to science. Although the meanings of these terms as used in this publication are not quite the same as mine, I think that the similarity of underlying views will be evident from a few brief quotations:

> "One of the basic objectives of science teaching should be to underline the interdependence of knowledge and action. This concern should lead to dovetailing science teaching and the teaching of technology, to highlighting the relationship between research and the practical development and application. But just the opposite is happening today. Within the educational system generally, we are introducing a sharp separation between science and technology, a separation which is damaging to both. In general education, curricula are far too prone to make room for sciences rather than technology. By shearing it away from the practical side, a part of science is sterilized on the pretext of giving it greater prestige and, as a result, it loses much of its effectiveness as an educational tool. An understanding of technology is vital in the modern world, and must be part of everyone's basic education. In present day general education, technology is not treated in a systematic, conceptual fashion".

One other short quotation from the same publication:

> "As technology affects more and more people, compelling them to understand and master the technical world, so education in theoretical and practical technology becomes necessary to everyone. Rigid distinctions between different types of teaching – general, scientific, technical and professional – must be dropped. And education, as from primary and secondary levels, must become theoretical, technological, practical, and manual at the same time. If so-called general education is to become truly general, technological education must be developed".

Even if it be agreed, for the above and/or other reasons, that we should teach both science and technology to all students, that still leaves unanswered questions of how, how much, when, etc. Time does not permit me to discuss such matters in detail, but I would like to give you my general views. First of all, should technology be taught as a separate subject? I think that the answer should be 'no' for various practical and theoretical reasons. On the practical side, given the already overcrowded curricula, the chances of squeezing in technology as a subject separate from science are negligible; arguments based on the importance of the distinctions between science and technology would not sound very compelling to the educational decision makers. Furthermore, the establishment of separate courses in science and technology in the early school years would run counter to the present, and I think laudable, trend toward more and more integration of the entire educational programme; if the teaching of science and technology can be woven together, they should be. Finally, I think they can be woven together – and with profit – although it would take considerable care and ingenuity.

How would one develop a programme in which a child would learn both science and technology, would learn the nature of both, their relationships and differences, without getting everything confused? We can start with one consolation – things are rather confused already (some things labelled 'science' are in fact problem-solving activities; some things labelled 'technology' at the secondary level in some countries are in my opinion really applied science, etc.); almost anything is likely to help. More to the point however, I think we get our most important clue from a recognition that both of these areas of human activity with which we are trying to acquaint the child involve two essentially different kinds of things, both of which he can learn, viz., the process and the product. Furthermore, when and if hard decisions have to be made about relative priority, I think that first importance should be attached to learning the nature and inherent limitations of the processes; therein lie the essences without which study of the products cannot make complete sense.

Fortunately, at least in the area of science education, part of the rationale behind the recent reform efforts was to help the child learn the process of scientific inquiry. Of course, in the implementation we are making some mistakes (e.g., mistaking any form of student activity, worthy enough in itself, as the 'inquiry' method; or failing to distinguish between the essence of the research process and a lot of subordinate processes), but we are moving in the right direction. The fundamental educational principle is that processes like research or design are not learned by reading books about them, or listening to lectures, but by *practice* – ideally under skilful supervision. Hence, in my opinion, in teaching both science and technology, the most important (but, of course, not the only) form of learning experience would be direct student involvement in the processes – at a level of sophistication appropriate to the child.

How early can these processes be taught? I don't know – and I don't know whether a lot of research has been done to determine whether there are stages of mental development below which the child cannot understand these different processes. Certainly our efforts to teach the rudiments of the inquiry method of science at the beginning elementary levels seems to imply an assumption that the essence of this method can be comprehended at these early ages. If this be true, I would hypothesize that the design (or decision-making) method can be learned as well and that one could therefore try to teach both processes in an integrated programme for science and technology.

But, precisely how? That I can't answer; I have no direct experience – and I suspect there hasn't been much experimentation anywhere with the kind of programme I have in mind; I hope I can interest others who are in a position to try it out to do so. However, there are a few general guidelines which I would follow if I myself had an opportunity to develop and test programmes in this area. First of all, although I find the phrase 'integrated science' meaningful, conveying the sense of an intrinsic unity underlying and binding together all the more specialized sciences, I find no useful meaning in the phrase 'integrated science and technology'; I can visualize trying to achieve various modes of integration of the sciences, for they are fundamentally the same, but I cannot conceive of any true integration of science and technology, for they are as different as oil and water. So, I wouldn't try to 'integrate' science and technology; I would try to teach both in an integrated programme.

Secondly, as implied earlier, the heart (but not necessarily the bulk) of the programme would involve confronting the student with 'realistic' (and, where possible, real life) situations, with a level of complexity scaled to the level of the student's development, in which he could gain direct, personal experience with the separate processes of seeking knowledge (research) and problem solving (design). I think it would be not only exceedingly important but, in fact, relatively easy to help the student see the contrasts between these two processes – and also the relationships. One way of illustrating the relationship could (and *would* be, if the educational programme were well designed) a natural by-product of the student's experience with the problem-solving or decision-making process. The student could easily be led to see that the quality or adequacy of the 'solution' which a designer develops depends in part upon the extent of his knowledge of some of the underlying phenomena; if the designer knew more, he might be able to develop better solutions (if we knew more about how children learn, we might be able to design better programmes; if physicians knew more about cell chemistry, they might develop more effective cures, etc.). Therefore, one could actually contrive student projects which would be linked but distinct; while undertaking one project in which he must decide what should be done to solve some problem (environmental, nutrition, safety, etc.), the student might conclude that he needs more knowledge of some relevant phenomena and would then generate a distinct but related research project. I can conceive of no better way of helping students learn the different processes involved, as well as the relationships between them.

Before leaving this section on the educational implications of the differences between science and technology education, I must point out that there is one whole area of what might properly be called technology education which I have not touched at all. In relation to technology, I've concentrated exclusively on the human activity of finding new and/or better ways getting a job done, of making decisions, solving problems, etc.; I've said nothing of the related area of human activity which necessarily follows, namely, of actually *doing* the job, of implementing the decision as made, of carrying out the plan as formulated. Whatever the nature of the project or problem, the implementation of the solution or plan almost invariably involves people carrying out specialized tasks in skilful ways – the skills of a surgeon, or bricklayer, or computer operator, a nurse, an automotive mechanic, a typist, a teacher, an electronic technician, etc., etc. In fact, some of the people who have mastered special skills and techniques are called technologists or technicians, and some of the educational programmes in which they receive their training carry 'technology' designations (degree programmes in engineering technology, medical technology, etc.). In my opinion, in an integrated programme of science and technology education at the elementary level, I think it would be possible (indeed, quite easy and natural) to include an implementation phase of projects and thereby to help the students to relate this activity to those of 'knowledge seeking' and 'problems solving' to which I have devoted the bulk of my attention.

5. Designing Programmes for the Education of Teachers

This Conference is concerned with the education of teachers of integrated science, and I have spent considerable time on asking the question 'what is integrated science', and have in fact proposed that we should have, at least at the early levels, integrated programmes in science and technology education. However, regardless or what exactly each of you would mean by a programme in 'integrated science' or 'science and technology', this Conference is concerned with various aspects of the question of how one educates teachers to implement such a programme. As stated in my Introduction, one of the purposes of this paper is to present an overall frame of reference for the more specialized plenary and working sessions which will follow and I want to do this by discussing the question of designing programmes for the training of teachers of integrated science (or of science and technology). This will have the additional advantage of being one illustration of the design process about which I have spoken at such great length.

I have tried to depict the task of the designer of an educational programme in a very condensed and summary form on Figure 2. In principle, this diagram is sufficiently general for it, with at most minor modifications, to be relevant to the design of any educational programme – of whatever duration, level, type, subject, etc.; I shall discuss it in terms of teacher education programmes and will hope that, if you are interested, you can transform its application to other types and levels of programmes.

Factors in the Design of an Educational Programme

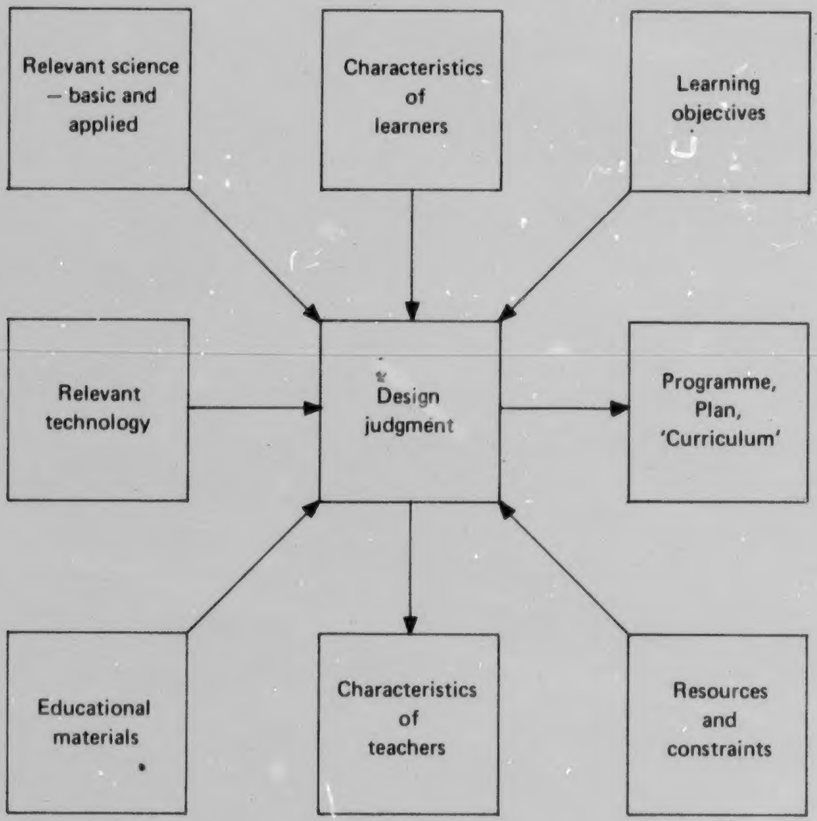
Relevant science – basic and applied
Characteristics of learners
Learning objectives
Relevant technology
Design judgment
Programme, Plan, 'Curriculum'
Educational materials
Characteristics of teachers
Resources and constraints

Figure 2

In considering this figure, the place to start, in my opinion, is at the output – the product of the design process. What I have in mind is essentially an outline of the various learning experiences which are planned for the student; it would be analogous to a musical score, showing the sequencing of the orchestrated inputs to the learning process – indicating the types of learning situations employed (lecture, laboratory, discussion, problem session, etc.), the roles of the teachers, the contributions of books, films, models, etc., the types of student activity, etc. Except for the fact that the term 'programmed learning' is usually used in a restricted sense to mean the very detailed planning of a sequence of learning experiences (frequently not involving a teacher) intended to achieve precise and limited learning objectives, one could employ the term in a broader and more appropriate sense here; with the understanding that the plan need not be as detailed as is usually implied, and that it could be as flexible as necessary (self-adapting, in fact), one could rightly say that the designer is involved in preparing a 'learning programme' (some might use the term 'curriculum', but I find that a relatively useless word because it means too many different things to different people – things ranging from a list of courses in a four-year 'curriculum' to a syllabus identifying topics, but rarely being the overall orchestrated plan which I think is needed).

If the designer is to develop an *optimum* programme, one that does the best possible job under the conditions that apply, he must take proper account of a large number of factors, some of the most important of which I have shown on the diagram as inputs to the design process. The diagram displays only the role of the designer and therefore assumes that, in that capacity at least, he has no control over the various 'inputs' or factors which he must take into account; in reality, the same individual might, in other capacities, help specify the objectives, or determine the types of students admitted, etc. For this presentation I am not considering these other processes, which require different procedures and skills.

Turning now to the individual inputs, and speaking in terms of the education of teachers, perhaps the place to start is with the objectives of the programme – the designer must know what things we want these future teachers to learn. If one were to do this properly (I suspect that it rarely is), we would have to begin by asking 'what is a teacher?' I can't dwell on this point, but I think that you will agree that, the word 'teacher' embraces a number of possible different roles (varying with level, country, situation, etc.), some of which are suggested by terms like 'objective specifier', 'learning facilitator', 'materials designer', 'achievement evaluator', 'programme designer', etc. Each of these roles requires, for its proper execution, different understandings, skills, etc. Self-evident as it may sound, one must carefully analyze what various roles the teachers are in fact going to play in order to design optimum programmes to prepare them for these tasks.

Still in connection with objectives, it is exceedingly helpful to the designer if they are identified in terms of the psychologically different things which students learn – *concepts* (energy, flux, justice, etc.), *principles or laws* (second law of thermodynamics, Newton's laws of motion, etc.), *skills* (verbal, mathematical, manual, etc.), *attitudes* (towards self, science, society, etc.), *facts* (the gram-atomic weight of hydrogen, the speed of light in a vacuum, etc.), etc. These distinctions are important because the best situations or techniques for helping a student learn facts are almost certainly different from those used to develop skills, or attitudes, etc. Therefore, unless the objectives are analyzed in this way, it is difficult for the designer to make the optimum selection and blend of learning situations (lecture, laboratory, practice teaching, etc.).

Finally, still on the matter of objectives, in designing a programme for the education of teachers of integrated science (or an integrated programme in science and technology), it would be exceedingly important that it be clearly specified what these future teachers are themselves to learn in the area of science and technology – what concepts, principles, skills, etc.; if the teachers are to help future students learn the processes and products of science and technology, what, and how much, must they themselves know?

Proceeding counter-clockwise on the diagram, the next factors which the educational designer must consider very carefully are those characteristics of the students which affect the way in which they might respond to the learning experiences provided for them. Clearly the details of a programme for the education of teachers depends upon such 'characteristics' as their number, their intellectual ability (general level, as well as variations), their motivation, their previous education, their sociocultural background, their physical and emotional health, their language abilities, etc., etc. One of the many reasons why educational programmes usually cannot be merely transplanted from one country to another is the very important differences in the characteristics of the students – perhaps not so much in intellectual ability (as measured by I.Q. tests) but in all the other characteristics which directly affect their overall performance as learners.

In planning the details of a programme for the training of teachers of science and technology, it would be exceedingly important for the designer to know as much as possible about the prior exposure of the teacher trainees to science and/or technology because it may even be necessary to help them 'unlearn' certain concepts, notions, or attitudes which are at variance with, for example, an integrated view of science. Did the future teachers study science at the elementary level; was it memory-dominated, or inquiry-oriented, or descriptive? At the secondary level, did the future teachers of integrated science take no science, one or more completely separate courses (biology, physics, etc.), or integrated science?

On the diagram, the next factor is 'relevant science (basic and applied)'. The sciences I have in mind are those which are relevant to the design of an educational programme, those which shed light on the learning process and on the dynamics of learning situations. By 'basic sciences' I mean those concerned with the *natural* phenomenon of human learning – ranging from the psychological and neurological framework through the interactions of group dynamics, etc. Consistent with the terminology used earlier in this paper, by 'applied science' I mean educational science – that infant and undeveloped discipline which, in due time, will help us better to predict what results will be achieved in the various situations and environments which we deliberately create (i.e., 'man-made') in order to promote learning. In reality, sad to say, the amount of useful knowledge which the designer can extract from this 'input' is not exceedingly large; a great deal more basic and applied research needs to be done. Nevertheless, we do know things about concept formation, skill development, attitude change, motivation, etc. which would help the designer try to optimize various parts of the overall programme. Incidentally, to forestall possible confusion, I should emphasize, before proceeding to the next design factor, that by 'relevant sciences (basic and applied)' I do *not* mean the sciences of physics, chemistry, etc. which might be a part of the training of the future teacher; these are contained in the diagram under 'learning objectives' (in my view, one specifies the 'content' – I don't really like that word – of courses by identifying what the students are to learn).

The distinction just made also applies to the next factor shown on the diagram – 'relevant technology'; by that I do not mean the technology that the student teachers are to learn but the reservoir of technology that can play a role in an educational programme. As outlined earlier in this paper, by technology I mean techniques, methods, processes, devices, materials, systems, etc. which have proved their usefulness in accomplishing certain tasks. On the diagram, I have not distinguished between 'general technology' (by which one might mean techniques and devices which are useful in a multitude of applications) and 'educational technology' (by which one *might* mean – it is a phrase with many different current usages – technology especially developed for educational applications). In any event, as I have conceived this input to the process of educational design, it covers everything from standard teaching techniques to the use of satellites for education – and embracing films, slides, computer-assisted instruction, micro-teaching, closed circuit television, etc. etc. Clearly the designer has a wealth of things to draw upon; indeed, one of the problems of the educational designer is that of keeping abreast of the many new technological developments which have direct implications for facilitating learning and which therefore might enable him to design a more effective programme.

As you see on the diagram, I have a separate input labelled 'educational materials'. Actually, this is closely related to the preceding input; in fact, I'm not able to explain even to my own satisfaction how one makes the distinction between these two inputs in all cases. In general, the preceding input is like the 'medium', this one concerns the 'message'; or, in related current jargon, the former is the 'hardware', this is the 'software'. The implied distinctions work well in many cases – the 'Socratic dialogue' is a technique (medium) which can be used in many different content areas (messages); radio broadcasting facilities are independent of the messages they carry. The distinctions get trickier (in my opinion) in the case of things like books, and disappear altogether (perhaps?) in the case of educational models, special laboratory kits, etc.

In any event, the dividing line between these two inputs need not detain us; for our purposes it is necessary merely to note how important it is that the designer take proper account of what educational materials are available (and, equally importantly, the characteristics thereof – cost, level of difficulty, etc.) to contribute to the overall effectiveness of the programme. For example, as part of the preparation of teachers of integrated science, one might include a science course taught in an integrated way. In so doing, the course designer would have to consider very carefully the extent to which materials are available that are suitable for the objectives of the course, the level of the students, etc.; lacking adequate materials, various allowances would have to be made in the design of the course.

The role and importance of the next factor, 'characteristics of the teachers', are surely self-evident. In this diagram, I am thinking only of the teacher in his role as 'learning facilitator' – one whose task it is to help the student in various ways (dialogue, lecture, questions, demonstrations, etc.) and in various settings (classroom, laboratory, lecture hall, etc.) to achieve his objectives. In some instances, as I pointed out in the discussion of 'what is a teacher?', the individual who is a 'learning facilitator' may also be a course or programme designer. In any event, the proper design of a course must take careful account of the characteristics of those who will teach it – their number, their age, the level and recency of their training in 'subject matter' and pedagogy, their prior teaching experience (and styles associated therewith), their attitudes (towards students, and teaching in general), their age, their socio-cultural background, physical and mental health, etc.; the history of educational reform efforts contains many examples of failures traceable to false assumptions (conscious or otherwise) regarding the characteristics of the teachers – particularly their willingness and/or ability to adapt to new materials and/or methods.

This is a factor of special importance in the training of teachers of integrated science; what can be assumed about the characteristics and behaviour of the teachers of these future teachers? Will the future teachers of inquiry-oriented elementary science courses learn their science from teachers who exemplify out-dated methods? The lack of 'teacher trainers' with the proper attitudes and methods could be a most serious problem for the designer of programmes for the education of teachers of integrated science.

The last factor, labelled 'resources and constraints', is a kind of miscellaneous category, which, in spite of that, includes many very important elements which affect the intelligent design of educational programmes but which have not yet been mentioned. Incidentally, before enumerating items which I have in mind, let me admit that in some cases, the distinction between a 'resource' and a 'constraint' is merely the point of view; the sum of *money* available is, at one and the same time, a resource and a constraint. Besides the all important factor of financial resources, there is the question of *time;* one always has limited time, and less than one would like. Another constraint which frequently affects educational design is legislation of one kind or another – ranging from laws regarding compulsory school attendance, to legislation requiring the teaching of certain subjects (e.g., national or local history), or even forbidding the teaching of certain things (e.g., the theory of evolution). An even greater constraint on educational design, especially if it involves innovation, is the tremendous inertia of educational systems, with their traditional ways of doing things; many a worthy reform has failed because the innovator failed to take account of the resistance which might come from students, parents, teachers, administrators, ministry officials, etc.

I have had to describe hurriedly these various factors which affect the design of educational programmes and to do little more than hint at the special applications to the development of programmes for the education of teachers of integrated science; the entire subject deserves a lot more attention and I hope that during the remainder of this Conference, in the sessions where some of these topics can be discussed, you will find the framework which I have sketched helpful. I realize that educational programmes are not often designed in the somewhat idealized way that I have described, but that may be part of our problem.

6. Special Opportunities and Problems

As indicated in my introduction, my last objective is to say a few words about some of the special problems and opportunities associated with the development of programmes for the education of teachers of integrated science (or of integrated programmes of science and technology). It seems to me that the major problems, and by the same token the greatest opportunities for improvement, are associated with two broad areas – the manner in which our future teachers learn science (and/or technology), and the manner in which they acquire the skills they need as teachers.

I think that it is true that, with rare exceptions, teachers of integrated science are being asked to teach what they have not learned. How can we expect teachers, who have science only in specialized packages, and by methods which may have stressed lecture and memorization and avoided direct involvement in experimental work, to completely depart from this background and teach science in an integrated and inquiry-oriented manner? The situation seems to me to be intolerable, on the whole, and I hope that some of you, back in your countries, will be able to work on changing the way in which future teachers of integrated science learn their subject.

Passing quickly to the second area, I think there is much room for improvement in the pedagogy component of the training of science teachers. Education courses are exceedingly important, I insist. But, rather universally, they have a poor reputation – as being dull, poorly taught (of all things), irrelevant, unchallenging, etc. My own very limited personal experience (in addition to a background in science and engineering, I have an advanced degree in education) suggests that, by and large, these courses deserve the reputation they have. This must be changed – and I think it can be changed if we will slaughter some of the 'sacred cows' of education (some of the traditional courses in education – methods of, history of, philosophy of, principles of, etc., etc.). I think that we must examine very carefully the question 'what is a teacher', the various roles he plays, and derive from this the concepts, principles, skills, attitudes, facts, etc. that he needs. We might then be able to design optimized learning experiences to help teachers prepare for their future roles. I hope that many of you see the opportunities for innovation in this area and, both during this Conference and back home, will channel your energies into it.

7. Conclusion

In this opening presentation at this Conference concerned with the education of teachers of integrated science, I have tried to focus on a few questions which are basic enough to be relevant to all of the more specialized plenary and working sessions to follow, for example, what do we mean by 'integrated science', and how should we go about designing programmes to prepare teachers of it? I've given you my proposed answers to these questions. However, whether or not you accept my answers is much less important than whether you accept the importance of the questions and will try to find your own answers.

INTEGRATED SCIENCE – A CHALLENGE TO THE SCIENCE TEACHER

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The Congress on the Integration of Science Teaching held in Varna, Bulgaria, in September, 1968, was concerned with the questions 'What is integrated science teaching?' and 'Why teach integrated science?' The present Conference, coming four and a half years later, is essentially concerned with the question 'How can integrated science courses be implemented?' Thus, in four and a half years, we have witnessed a shift in emphasis from the 'what' and the 'why' of integrated science teaching to the 'how'. During these four and a half years, it has been my privilege to view from the vantage point of UNESCO the unfolding of a vast array of integrated science teaching projects and programmes in every corner of the globe. These programmes embody a wide range of different approaches to integrated science teaching, including 'process', 'concept', 'unit', 'environmental', 'applied science', 'thematic', 'project' and 'pattern'. There are doubtless others, and in any case it is rare to find a programme which makes use of one approach only. A major constraint in implementing these programmes is the challenge which they present to the teacher. It is this challenge which is the central theme of our Conference.

As a prelude to considering the nature of this challenge, it may be helpful to consider the nature of modern integrated science courses, and their historical evolution. UNESCO's own programme in integrated science teaching was launched in response to requests for assistance from several Member States of UNESCO to devise science courses which contribute to the general education of all pupils. In 1969, when this programme was launched, there was widespread concern that school science courses should not be conceived, as in the past, solely or mainly as a preparation for the pursuit of scientific studies at higher levels. This idea of science education was, in fact, affirmed at the Varna Congress on the Integration of Science Teaching already mentioned, [1] and some of the characteristics of such a science course were elaborated there. It was agreed that to contribute effectively to general education, a science course should emphasize to pupils the importance of observation for increased understanding of the world about them; it should help them to appreciate the modes of thought and the ways of work characteristic of science; it should help to develop their interest in science, and should bring to their attention some of the major science-related problems facing mankind as a whole and their own society in particular. In relation to such considerations, integrated science teaching has been defined as 'those approaches in which the concepts and principles of science are presented so as to express the fundamental unity of scientific thought and to avoid premature or undue stress on the distinctions between the various scientific fields'. [2]

The implications of these ideas are far-reaching. In countries where the vast majority of children do not continue their formal schooling beyond the primary or lower secondary level, science courses must be designed which are not only foundation courses, but terminal courses as well, in the sense that they may be the pupils' only formal scientific preparation for adulthood. The development of an appropriate science curriculum for this level of schooling must therefore receive important attention. Thus, Unesco's programme was launched with a particular emphasis on elementary schools and the lower grades of secondary schools, and with the training of teachers for this level of the educational system, although higher levels were not completely excluded. It was also conceived as a co-operative programme with UNICEF, which would be executed in close collaboration with the ICSU Committee on the Teaching of Science. Its overall aim is 'to stimulate and strengthen the scientific attitudes and skills of children and to promote science teaching – both appropriate to local needs and consonant with modern views of science education – in primary schools and the lower forms of the secondary schools, bearing in mind that science teaching should be integrated as fully as possible into the overall curriculum'. In pursuing this aim, emphasis is placed on the importance of initiating such programmes at the primary school level, in order that science may be introduced at the earliest grade possible thereby reaching the largest group of children while they are still in school.

From 'general science' to 'integrated science'

The need to devise courses covering the whole range of the sciences in a balanced way was widely felt some 40 years ago. The teaching strategy then devised was to develop 'general science' courses. Such courses were co-ordinated surveys of physics, chemistry and biology. Only rarely was there real unity in the presentation of the course. In some cases, an attempt at unity was made through a 'topic' approach. With some notable exceptions, the teachers failed to achieve any real integration in their teaching, partly due to lack of real guidance in how to do this; rarely did teacher training courses prepare teachers for a unified approach to their teaching.

Two advances in other areas provided the key to the design of courses that are, in fact, integrated. In the first place it became clear that the major advances in scientific research are taking place in interdisciplinary areas – molecular biology, geophysics, biochemistry and astrophysics, to name a few. Such advances were often the results of methods and techniques developed in one scientific field being applied to the subject matter of another. This emphasized the unity of science – the fact that the boundaries which had formerly been taken for granted were becoming blurred and illusory.

The second break-through came in science education itself when the first large-scale curriculum projects developed new courses in physics, chemistry and biology, and later in earth and space science. Physics was no longer a mixture of light, sound, dynamics, hydrostatics, electricity and magnetism. Physics itself became unfied. The major concepts were identified. School children were introduced to the idea of building models to explain phenomena on the basis of existing knowledge. It could no longer be said that chemistry was primarily concerned with encyclopaedic masses of facts. Courses in biology replaced those in botany and zoology. In each of these disciplines some major principles were developed as threads with which to weave a fabric that highlighted the methods and processes actually used by investigators in these fields. These programmes all embodied a radical change in teaching approach. They encouraged pupil investigation rather than teacher demonstration – a shift to 'let's find out by experiment' from 'let's verify'.

We have thus a situation in which the design of integrated science courses seems the next logical step in the evolution of science courses. As already indicated, there is a variety in the 'approach' to integration and in the methods used to achieve it, but each course in its own way draws on the insights outlined above which were acquired during the last decade of curriculum development. In the courses which have recently been developed, teachers are required to draw upon science as a whole, and to teach it in a meaningful way to the child in his own particular environment.

At this point, however, we may mention two other factors which have had a considerable bearing on the type of courses that have been designed. The first is a growing awareness of the need to be concerned with the nature of the learner – and his all-round development – psychological, social, physical and emotional. In the past, it was largely the logic of the subject matter which governed the order in which it was presented. Today, when the research findings of the psychologists have shown that the 'logic of the child' differs very considerably from 'the logic of the subject', an attempt is being made to design courses related to the child's intellectual and overall development.

A second, and related, factor has been a growing awareness that the influence of science and technology on society is so enormous that it cannot be ignored in general education. Thus, the social effects of science and technology have had a big influence on the design of integrated science courses.

Aims and objectives of integrated science teaching

If, in the light of this brief historical survey we come to review the overall aims of current integrated science programmes, we find these three aspects reflected, i.e.

(a) the nature of science
(b) the nature of the learners
(c) the nature of society.

(a) *The nature of science* is reflected in essentially four aspects:

(i) the simple cognitive skills, such as the ability to recall knowledge, comprehend the basic concepts and themes of science such as the nature of matter, energy and its transformations, the nature and properties of living things, etc. and their application in novel situations;
(ii) the process skills such as the ability to observe, measure, classify and predict. It is these skills that will largely influence the way in which the subject matter is taught;
(iii) the development of attitudes such as honesty and open-mindedness, and of the realisation of the tentative nature of scientific theories. These are unlikely to arise from the courses unless the approach to practical investigation reflects true enquiry;
(iv) the skills appropriate to science. These would include not only the ability to manipulate apparatus, but to construct and interpret tables, charts and graphs, as well as to be able to find relevant information from sources of reference.

As indicated earlier, some courses place more emphasis on one of these aspects and some on others, but all four are found in most courses.

(b) *The nature of the learners:*

It seems that many integrated science teaching programmes, most of which cover a period of several years' schooling, attempt to reflect the findings of research in the development of science and mathematics concepts in children. For example, the project 'Science 5/13' [3] in the U.K. organizes its general objectives into three stages corresponding with different developmental stages of children as outlined in Piaget's theories. The African Primary Science Programme [4] lays great emphasis on the cultural and social background in which the child finds himself. The Australian Science Education Project [5] states specifically: 'The broad aim of the Project is to design science experiences which contribute to the development of children'. In a word, there appears to be considerable awareness in the designers of integrated science schemes that curriculum development should be geared to the thought of the child, and not just to the logical structure of the subject.

(c) *The social significance of science and technology:*

This affects integrated science courses in two ways:

- In the selection of aims for the course as a whole, greater attention is paid to the overall needs of society. For example, the Project for Science Integration in Ghana [6] canvassed widely public opinion in the country before drawing up the aims of its integrated science course, and reflected it in its statement of objectives. One reason for the widespread popularity of integrated science courses is an awareness that they can better reflect the aspirations of society than courses in a single science discipline.

- In the selection of subject matter, the social significance of science has been given prominence, and technology has also crept into 'integrated science' courses. Thus, the Schools Council Integrated Science Project places heavy emphasis on the interaction of science, technology and society. In the Australian Science Education Project, aspects of social science are also included.

The nature of the challenge

Here, then, is the situation confronting the science teacher, in service or in training. His own education will have taken place at some point in time along the continuum from 'general science' to 'integrated science'. He may have been taught general science at school, or one or more of the separate sciences. It is unlikely that he, himself, will have been taught in an integrated way. It is notorious that teachers teach as they themselves were taught, but for the teacher who is to teach integrated science, a major change in approach is required. As far as integrated science courses are concerned, a multiplicity of possible approaches confronts him. He may or may not have some choice in the question of which one to follow. Whatever course he follows, it will certainly demand much more of him in various ways than has hitherto been required of the science teacher.

The first demand relates to the role of the teacher of integrated science programmes. Is he just to be a learning facilitator as he has been traditionally in the past – or is he to be more intimately concerned with formulating the objectives, designing the materials and playing a part in the evaluation of his programme? The teacher himself may not be too sure of his role, and he may not feel too comfortable about the new roles which many integrated science programmes call on him to fulfil. A related consideration is the role which society itself thrusts on him. Society (including both the pupils he teaches and their parents) thinks of the teacher as the person who has all the answers. But it is in the very nature of the scientific enterprise to be asking questions for which no-one has the answers. Modern, integrated science programmes emphasize this aspect of the nature of science much more than traditional programmes have done. The teacher must be able to say 'I don't know' without feeling uncomfortable about it.

A second challenge to the teacher is in the content of integrated science courses. As far as scientific content is concerned, the courses will often be wider in scope; they may include aspects of technology and social science, and the teacher may rightly ask – 'how am I to handle all this material'? There may also be more understanding needed of the process of scientific investigation. There is perhaps a deeper understanding required, too, of the 'big ideas' of science – the unifying principles. If, as in the 'Schools Council Integrated Science Project' we have three unifying principles – the principles of 'energy', 'building blocks' and 'interactions', then the teacher must have a very good understanding of the significance of these concepts throughout the spectrum of the sciences.

As far as educational content is concerned, the teacher needs to understand the aims of a particular programme, and to make these aims his own as far as teaching the programme is concerned. However, in practice there may be conflicts between the teacher's aims and the stated aim of any particular course. Such a conflict may arise, for example, when pupils are required to take an external examination which does not accurately measure the major skills and attitudes embodied in the course. Thus, the teacher needs to understand how to put the stated aims of a course into effective practice, and how to evaluate to what extent he has succeeded.

The teacher also needs to have an understanding of his pupils' capabilities and their level of cognitive development. Some of the new curricula, such as the 'Intermediate Science Curriculum

Study', place much greater emphasis on individualized learning. An understanding of his pupils' strength and weaknesses and their stage of cognitive development is essential if such an approach is to be effective.

Thirdly, modern integrated science courses present a challenge to the teacher in their teaching methods. The new materials provide the teacher with a wealth of ideas, stimuli and assistance for his teaching, but he needs to learn how to handle them. Reference has already been made to individualized instruction. There is also encouragement to make greater use of local materials and of the local environment in science teaching. There may also be many more 'open-ended' problems and situations which the teacher is required to handle. Such teaching provides great scope and flexibility, but the teacher may need to be helped to know how to exploit it to the full. The teacher may also need to know how to utilize effectively a range of technological aids in addition to the more usual laboratory skills. Similarly, more may be required of the teacher in terms of classroom skills such as asking questions, encouraging discussion and stimulating fruitful interaction among his pupils, than in previous courses.

A teacher placed in this situation will first ask the question 'why should I use the new approach?' i.e. he needs to understand it and to be convinced of its value. He then needs to know 'how can I do it?' He needs help, through suitable training courses, in understanding the purposes of these materials and in using them to their best advantage. Finally, he needs self confidence which comes through trying out the new approach.

I should like to suggest that these are three of the most important aspects of the situation confronting the science teacher to which we should address ourselves. As far as the 'why' is concerned, the greater potential for the education of his pupils in integrated science courses – 'education through science' as it is sometimes put – may be a powerful argument. The excitement of many of the new programmes and the satisfaction the teacher as well as the pupil can get through following them can help to achieve conviction. We also need to convince the teacher who regards himself as a subject specialist in one of the separate disciplines that integrated science is intellectually and professionally 'respectable'.

With regard to the 'how', the classroom materials are already there in great profusion, but the need remains to gear our training programmes, especially our pre-service training, to the effective use of them. One of the greatest weaknesses in this recent wave of curriculum development has been inadequate attention to preparing materials for teacher education, i.e. for the use of teachers of teachers. The Science Teacher Education Project in the U.K. may help to point the way forward here.

But it is perhaps in engendering self confidence that we have our greatest challenge. I would venture to suggest that if we find mechanisms for involving the teacher in the process of curriculum development and design of materials and their trials in the classroom, such involvement will make the greatest contribution to his self confidence in using them. What are such mechanisms? Science education centres, teachers' centres, science teachers' professional associations, all have their contribution to make. Whatever the most appropriate mechanism in any particular situation, it must be geared to continuous teacher renewal. 'Curriculum renewal' and 'teacher renewal' go hand in hand.

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DESIRABLE CHARACTERISTICS OF TEACHERS OF INTEGRATED SCIENCE

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The short range goal of this paper is to identify some desirable characteristics of teachers of integrated science. The long range goal is to provide thoughtful science educators throughout the world with some insights, directions, and goals that will be useful in preparing teachers to teach integrated science. I have assumed that there is general agreement on what constitutes integrated science. I realize that this may not, in fact, be the case even though the whole conference has been planned on that assumption. I have further assumed that, for the purposes of this paper, the terms integrated science and unified science are synonomous. My own experience favours the latter and distinguishes it from the former. These distinctions in operational terms can be found elsewhere [1] and will be overlooked here in the belief that doing so will facilitate communication.

Background and Basis for Comments

The ideas presented in this paper are based on personal experience dating back to 1959. At that time I became involved in developing and teaching a unified (or integrated) science curriculum at the laboratory school of The Ohio State University. Since then, I have taught unified science at many grade levels, conducted a longitudinal study of the effects of a unified science curriculum on high school graduates, and worked with teachers in developing their own unified science programs and, hopefully, helping them become better teachers of unified science.

The latter effort has been centred on activities of the Federation for Unified Science Education (FUSE). The group was formed in 1966 by teachers from the eight secondary schools in the United States which were involved in developing unified science programs. The purpose of FUSE at its inception was to serve as a source of mutual help in solving problems associated with unified science curriculum development.

The original purpose of FUSE continues today even though the number of teachers involved has expanded tremendously. Today, there are more than 100 secondary schools in the United States that have unified science programs under development. Other programs, though fewer in number, exist in elementary schools and colleges.

The efforts of FUSE have been strengthened greatly by the establishment of the Center for Unified Science Education at The Ohio State University. This important step forward was facilitated greatly by a grant from the National Science Foundation in June, 1972.

I believe that it is significant that FUSE originated and operates as a grass-roots movement that capitalizes on the talents of science teachers themselves.

Curriculum Problems Caused by Teachers

During the past twenty years of intense science curriculum development, it has become increasingly apparent that there are no instructional materials which are 'teacher proof'. That is, designers and writers can conceive and produce science instructional materials which should enable learners to achieve almost any goals. However, when placed in the hands of teachers, the materials all too frequently get used in ways and toward achieving objectives other than those which the designers intended. Since the introduction of integrated science programs undoubtedly will be accompanied by sets of instructional materials, it is important that we anticipate those problems that teachers may have (or cause) in using the materials in the spirit of and to the ends for which they were conceived and developed.

To be forwarned is to be forearmed and, in this case, we as teachers of teachers may be able to provide learning experiences that will forestall the problems that, if not treated properly, could cause a whole program of integrated science to fail.

There are at least three frequently occuring ways in which teachers misuse science instructional materials which are intended to teach scientific inquiry. The heart of scientific inquiry is to draw conclusions from evidence that has been obtained first hand and it is relatively easy to design and produce materials to facilitate this approach. However, when such materials are given to teachers, the inquiry aspect is overlooked completely. Thus, some instructional materials have been designed to teach inquiry and which use live mealworms as the 'vehicle' of learning. The teacher, who may or may not have attended an in-service workshop on this set of material, can miss entirely the intent of the materials by emphasizing that students learn all the 'right' facts about mealworms which the designers intended should at most be incidental. In so doing, the major purposes of the materials are overlooked completely.

The second common way teachers have of misusing science instructional materials is to use a method of teaching that is contrary to the objectives and purposes of the materials. A teacher could misuse the inquiry centered 'mealworm' materials mentioned previously by using a very didactic methodology. In this method the teacher would do things such as insist on certain steps of scientific method being used in order by every student in the class. He or she would probably also insist on every student preparing a report which adhered to a rigidly prescribed outline and which exceeded a specified minimum length.

In general, this second type of misuse of science instructional materials is that in which the medium contradicts the message. Marshall McLuhan and other eminent psychologists have argued quite forcefully that the medium *is* the message [2]. Yet we in education especially seem to have been very slow in recognizing this very potent principle of communication. Even today teachers-to-be must listen to lectures on the evils of lecturing in science education.

The third misuse to which science instructional materials are subjected is that of the teacher's acting as if he or she either did not learn or does not believe the main ideas developed in the materials. Evidence for this misuse is demonstrated before and/or after the materials are used.

For example, in the United States it is very common to teach one or more units on the metric system at several levels from middle elementary grades up through high school. Students are taught the various metric units, given practice in using them in association with scientific instruments, taught conversion factors, and examined on the knowledge and skills developed. This teaching is usually based on instructional materials that are effective and interesting to students.

Unfortunately, much good that may have been done is undone by the teacher who *never* uses metric units in daily conversation with the same students. In fact, it seems that the teacher who is most insistent that students be able to fill in the test blanks with the right words as grams, millimetres, etc., is the same teacher who is most incredulous when next year's teacher of the same students claims they have no working knowledge of the metric system.

This particular misuse has parallels in other areas of education and is described in 'non-technical' terms as failing to practice what one preaches.

Categories of Desirable Teacher Characteristics

All of the preceding section leads to the inescapable conclusion that the teacher is *the* key to developing successful unified science programs. We can now direct our attention to those characteristics of teachers that are crucial to the business of teaching integrated or unified science.

I have identified three categories that are appropriate for grouping the unique characteristics that the ideal teacher of integrated science should have. These are:

1 – Personal Philosophy of Science
2 – Personal Life and Teaching Style
3 – Personal Knowledge of Learners and Learning

Personal Philosophy of Science

The principle characteristic required of a teacher of integrated science is a personal philosophy of science that acknowledges the unity of science. In this kind of philosophy, the various specialized sciences are viewed as arbitrary sub-divisions of the larger science. The sub-divisions or specialized sciences are useful to scientists but the larger more general view of science is more useful to all people.

The unity of science philosophy views science as more than a collection of specialized sciences. From a unified science point of view, there are certain factors that permeate all the specialized sciences that exist today. The same factors will characterize specialized sciences of the future but that have not yet been created or formalized today. Once these factors are acknowledged as the essence of science, it follows logically that they should form the core of a liberal education in science for all people.

A thorough discussion of each of the factors that permeate all science is beyond the scope of this paper. However, it is appropriate to identify some of the major factors and give some examples.

The first of these permeating factors is the set of values that underlie science. There are seven humanistic values that 'characterize the enterprise of science as a whole'. [3]

1 – Longing to know and to understand
2 – Questioning of all things
3 – Search for data and their meaning
4 – Demand for verification
5 – Respect for logic
6 – Consideration of consequences

These values are not stated in traditional ways but ' . . . like all values, they are guidelines for belief and hence for action. Some of them merely define traditional values. For example, the demand for verification is nothing other than an approach to and a profound respect for honesty'.

A second factor is the idea that everything in the universe is part of the same universe. The American naturalist, John Muir, once said, "When we try to pick out anything by itself, we find it hitched to everything else in the universe". A simple experiment may be performed to amplify this point: close your eyes, turn your head at random, open your eyes, fix your sight on the first thing that captures your attention, start asking questions about that thing, record your questions, and finally categorize your questions. Consider the probability that anyone's questions will be contained totally within any category that corresponds to any one of the specialized sciences such as chemistry, botany, or geology. In other words, the organizing structure of the universe (if there is one) is not built of separate components called physiology, sociology, zoology, etc.).

A third factor that permeates all science is epistemological in nature. Theories developed in an attempt to explain the nature and origin of human knowledge typically identify science separately from other types of human knowledge. However, these theories do *not* distinguish between the specialized sciences. Thus, from an epistemological point of view, science is a unity. Within science and among the specialized sciences the same 'rules of the game' apply when it comes to establishing new knowledge. This is *not* the same thing as saying there is *a* scientific method. It's just that certain types of things carry conviction in science. Thus several principles can be linked together to form a theory all of which rests on empirical evidence that is public and replicable. The very fact that all of the specialized sciences aim to develop theories (i.e., knowledge), that are by nature probabilistic, sets science apart from other 'ways of knowing'.

A fourth factor closely related to the epistemological factor is that set of 'processes' which characterize science. These processes include: observing, inferring, classifying, quantifying, controlling variables, predicting, interpreting data, formulating hypotheses, modeling, and defining operationally. All the processes combined represent the dynamic aspect of science and most are closely connected with overt skills or behaviour.

Not only do the processes permeate all the specialized sciences but so do the word labels that identify them. Thus, it is quite possible for a chemist to visit a sociologist and ask intelligent questions about his methods of controlling variables and interpreting data. The fact that the question can be asked and understood accords 'processes' a powerful integrating role among specialized sciences and scientists.

A fifth factor is one that can also promote communication among specialized scientists. It is that group of invented concepts or constructs that seem to be useful throughout science. This group includes ideas such as equilibrium, model, field, and system which are used almost universally in science.

In the meeting of the chemist and the sociologist hypothesized earlier, the latter could have asked an intelligent question such as, 'What model of society are you using in your study'? Upon returning the visit, the sociologist can ask, 'What model of matter are you using in your study'? Both of these questions are 'good' because they are fundamental to each study and meaningful to each scientist. The concept of model is crucial to understanding what every specialized science is and what it is not. Thus, it follows that the concept of model is more central to science than are the details of any particular model.

Personal Life and Teaching Style

The second most important characteristic required of a teacher of integrated or unified science is a personal style of living that reflects the nature or spirit of science. That is, the teacher's behaviour in relation to students, colleagues, school administrators, officials, and the general public, *but especially to the pupils in the classroom,* should demonstrate application of the philosophy of science described previously.

More and more science educators are realizing that Marshall McLuhan is correct in saying, 'The medium is the message'. There is a pre-McLuhan American proverb that says, 'It's not what you do, It's the way that you do it'. Both of these expressions articulate the same idea. When the idea is applied to educational practices, it gives:

"What is learned is really the philosophy of the teacher as it is expressed in the way classes are conducted".

If a teacher of integrated science is to be successful, he or she must act so that classroom learning activities are consistent with a unified science philosophy. This means that the teacher must, for example:

1 – value students' questioning of all things. This must be done always – even outside the context of the science class. Thus, if a student questions the reasons for school practices being what they are or raises doubts as to the ultimate value of studying certain topics, the questions must be valued for themselves even if finding answers becomes an embarassing task.

2 – view his or her own teaching methods as application of a working hypothesis about teaching which is followed by collection and analysis of data which will be followed by modification of the hypothesis. Changes in teaching methods, etc., that result can be viewed for what they are – the result of rejecting certain working hypotheses *not* a rejection of the teacher as a person.

3 – find opportunities to emphasize the application of major principles and concepts in a variety of contexts that use material from the traditionally separate sciences as vehicles for learning. The teacher will never respond to a student's science question or interest by saying, "That is out of my field" but will say simply, "That is a great question but I don't know an answer" if that is the appropriate response. In some cases it will be feasible to embark with the student in a mutual effort derived from the students' questions,

4 – be more concerned with helping students learn the relatively few major concepts, processes, and values that permeate all science than with student acquisition of large numbers of facts which have limited usefulness in place and time.

Personal Knowledge of Learners and Learning

The third characteristic required of teachers of integrated science is an awareness of the nature of learners and the learning process. This awareness is needed by all teachers of all subjects, but is especially important for science and integrated science in particular.

The proper awareness would be manifested by the teacher acting as if he or she believed:

1 – the purpose of a school and curriculum is to help students learn, not to provide a vehicle for the teacher to satisfy his or her personal needs.

2 – individuals learn at different rates.

3 – individuals learn in different ways and even a given individual may learn in different ways at different times.

4 – certain individuals may not be able to learn certain things meaningfully because their present level of cognitive development does not permit it.

5 – individuals learn best when they are interested in learning.

As a result of this awareness about learners, the ideal teacher of integrated science will:

1 – utilize a broad mixture of teaching methods as opposed to using only one or two methods.

2 – advocate an evolving curriculum that over the years will change in response to the needs

and interests of students and society and to improvements in the school's technical facilities.

3 – work co-operatively and actively with colleagues on local, and, if possible, on state, national, and international levels to improve science education.

Summary and Challenge

In this paper I have attempted to identify several characteristics that need to be developed in teachers as a necessary precondition to the successful teaching of unified or integrated science. I have attempted to give some background and rationale that lead to these particular characteristics.

I have said nothing about how these characteristics might be developed within pre-service teachers or practicing teachers. I am convinced from my experiences with FUSE and the Center for Unified Science Education that there are many ways these characteristics can be developed with *experienced* teachers using certain techniques. However, there is a continuing challenge to invent effective ways of helping *all* experienced teachers and teachers in training to develop the desirable characteristics.

The challenge will not be easily met because the desired characteristics are as much in the affective as in the cognitive domain. Text books and memorized verbisms will *not* produce the desired effects. The *whole* education of the prospective teacher of unified or integrated science must be considered.

Someone once said that to travel hopefully is better than to arrive – and, as yet, no one has arrived.

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THE AIMS AND OBJECTIVES OF TEACHER EDUCATION FOR INTEGRATED SCIENCE, INCLUDING CHARACTERISTICS AND COMPETENCIES OF THE INTEGRATED SCIENCE TEACHER

Report of Working Group Wf

Chairman and Rapporteur: Herbert D. Thier, Lawrence Hall of Science, University of California, Berkeley, California

Make-up of the group

The group was made up of over 40 members from 28 different countries. More than half indicated that their major interest was the secondary school with about 30 per cent listing college or university responsibilities as their major interest. Only 7 of the group indicated the primary or elementary school was their area of major interest. Any discussion of aims and objectives of teacher education will quite naturally be related to the differing points of view regarding the tasks for which the teacher is being educated. In order to help the group understand the nature of its own make-up and as an aid to putting subsequent discussions into context, a survey was carried out in which each participant was asked to list up to three goals or objectives which they thought were of most importance for the teacher of integrated science. It is interesting to note that in this preliminary survey and in most of the rest of the deliberations of the group, the emphasis was on competence of the teacher as an individual rather than on an attempt to specify exactly what the teacher should accomplish. It was strongly felt by the group that specific objectives regarding the outcome of the teaching should be left to the teacher and the local school or educational agency after giving careful thought and consideration to the needs, prior experiences, and related educational opportunities of the group of learners. A review of the individual items mentioned in the survey provided a clustering of responses around certain general headings. The number following each statement indicates the relative frequency of the response.

Competency in integrated science	19
Understanding and transmission of the overall relationship of science to school and society	15
Flexibility and creativity in approach	14
Ability to convey competence to students	13
Methods (attitudes, humanistic approach)	12
The provision of experiences relating to the child's intellectual development	9

About six others were listed 1 – 3 times.

Discussion of the survey

It is important to note that competency in integrated science and an understanding of its relationship to other fields, the ability to transmit this competency to one's students and a concern for the pupil and his needs and capabilities were the major interests of the group as expressed in the survey. The emphasis on the desire for competency in the field was very strong and was re-emphasized continuously in the rest of the work of the group.

It was decided to divide the Working Group into four sub-groups, each responsible for one particular aspect of the overall question of aims and objectives. The first of these sub-groups considered the general classification of goals. Its report is summarized below in the form of a broad outline followed by examples of each of the major categories.

Overall Goals or Objectives of Teacher Education for Integrated Science (Outline)

Major Classification

I. *Pre-service objectives*
   (a) Common objectives for all teachers.
   (b) Specific objectives for science teachers
      (1) Objectives concerned with teaching; examples, methods, experiences.
      (2) Objectives concerned with the discipline of integrated science; examples, experiences.

II. *In-service training objectives*
   (a) Relation to pre-service objectives.
   (b) Attitudinal emphasis.

Example

I. *Pre-service objectives*
   (a) Common objectives:
      (1) To relate teaching activities to the nature of the natural, artificial, and cultural environments of his locality, country and, in general, the whole world.
      (2) To relate teaching activities to the stages of physical, social, intellectual, and emotional development of the child.
      (3) To know the cultural background and values of the people and make use of these in teaching.
      (4) To be responsive and to evaluate suggestions and questions of others involved in the educative process.
      (5) To pursue relevant areas of study to a greater depth.
      (6) To know the place of science education within the whole of general education.
      (7) To be aware of the educational technology available for teaching and be able to select the most appropriate for a particular course of studies.
   (b) Specific objectives for science teachers:
      (1) Objectives concerned with teaching methods
         a. To use a variety of teaching approaches, including the ability to establish an atmosphere for inquiry.
         b. To be able to suggest or devise experiments (which include the use of

materials available around the classroom or outdoor environment).

  c. To be aware of learning theory and its application to the understanding and use of scientific concepts and processes according to the child's development.

  d. To know a child's previous and present experiences (including those outside school) and the ability to use these in science teaching.

(2) Objectives concerned with the discipline of integrated science:

  a. To have some common body of knowledge in the different areas of science in order to understand the wider aspects of what is to be taught.

  b. To be able to design or describe a conceptual structure for integrated science.

  c. To be competent in the various processes of science.

  d. To understand the relationships between science, technology, and society and to attempt to perceive an overall picture of the effects of solving one problem on the total environment.

II. *In-service objectives*

(a) Many of the pre-service objectives are also valid in the in-service phase. In-service training could serve the following functions:

  (1) Remedial
  (2) Enrichment
  (3) Developmental
  (4) Implementation

(b) Much of the effort at this stage should be devoted to achieving attitudinal objectives. Some examples are:

  (1) To be willing and able to meet professionally with colleagues and to work as a part of a team.

  (2) To have an understanding of the society of which the school forms a part, and a willingness to interact with the other areas of society.

  (3) To be aware of various alternatives to the synthesizing of knowledge patterns and to be willing to change approaches to science teaching on the basis of this knowledge.

  (4) To be able to evaluate current trends in science education and to reject or accept the changes.

  (5) To have the opportunity to consider and to develop these curriculum ideas and to be given the time and resources to implement them.

Discussion of the findings regarding the overall goals or objectives of teacher education for integrated science

The subgroup on overall goals and the group as a whole was most concerned not only with the integration of the various sciences but also with the more general question of the relationship of the sciences to the other endeavors and experiences of the teacher and his students. For this reason, emphasis is given in the summary report to objectives which, it is felt, are common and vital for all teachers. These examples of common objectives and those mentioned for integrated science specifically emphasize the kinds of competencies one would like to find in the teacher, rather than trying to even indicate the number and kind of courses to be offered, facts to be learned, or even the length and extent of the training program. The emphasis is on the individual teacher's ability to use his knowledge and understanding of science and its relationship to other fields in conjunction with his knowledge and understanding of the learner as a basis for designing the instructional program in his classroom. The teacher is expected to teach integrated science in a way that reflects the spirit and nature of science interpreted in a way that is meaningful for the learner and helps him to relate his experience in science to his overall experience in, and growing understanding of, his environment and his relationship to it. Flexibility and adaptability are major characteristics implied throughout the statement on overall goals. At the in-service level, a strong case is made for the kind of teaching situation and training program which encourages the continuous development of these attitudes of flexibility and adaptability. During the discussion of these findings, considerable emphasis was placed by the group on providing the in-service teacher with opportunities for and encouragement to, carry on research and/or development activities of his own related to science or the teaching of it. This might differ greatly for individuals at different levels. The primary teacher might use Piagetian approaches to study the relative intellectual development of selected pupils in the class, while the university or college teacher may investigate a specific aspect of science itself. The intent for both was to insure that the teacher as an individual was continuing to have the opportunity to experience for himself the process of inquiry and analysis of evidence which characterizes all of science. It was felt that such opportunities for research type activities would encourage greater flexibility and adaptability in the teacher and the kind of learning environment he or she developed in the classroom.

While the subgroup on overall objectives continued its work, the rest of the group broke up into three subgroups to discuss and develop summary statements on the goals and objectives of teacher education for integrated science at the primary, secondary, and tertiary levels. A summary of the reports of these three groups appears below.

Goals of Teacher Education for Integrated Science

A. Primary level

(1) To learn the content and ideas of integrated science

(2) To examine the programs and materials that are available

(3) To learn the methods of science that are particularly related to integrated science

(4) To develop a scheme such as a web or a structure around which a teacher can develop his integrated science program

(5) To find how to broaden present discipline-oriented courses so that cross-relations are evident

(6) To look for the aspects of the culture that can be linked with integrated science

(7) To develop a spectrum of courses and units in integrated science so that no teacher will be unable to cope

(8) To lead to a tolerance for an idea of science that is not 'as clean as possible', so that teachers will enlarge their idea of science and its implications

(9) To develop a readiness to look at science in view of the needs of a country or a community

(10) To frame a type of program in integrated science to ensure that training college students have a satisfactory idea of science

B. Secondary Level

(1) To develop scientific attitudes to enable him to use them in decision-making processes.

(2) To understand the impact of science and technology on society

(3) To understand the role of science in the historical development of humanity

(4) To develop the ability to draw from a variety of sources.

(5) To help the teacher realize his role as helper or facilitator of learning activities of children in and outside of the classroom

(6) To give a broad background in science with a deep knowledge in certain areas, possibly of an integrated nature such as energy, structure of matter, earth science, etc.

(7) To give an experience of personal involvement in research type activities

(8) To have an understanding of the learning process as well as sensitivity to detect the needs and interests of the children, and the flexibility to adapt and modify the program to meet these needs and interests

(9) To develop manual skills for using simple hand tools to improvise science teaching aids from local resources if needed

(10) To find how to broaden present discipline-oriented courses so that cross relationships are evident

C. Tertiary Level

(1) In the near future most integrated science at tertiary level should be aimed at training teachers of science at the secondary level

(2) Higher level integrated science can be achieved by first studying the separate disciplines or by studying integrated science throughout

(3) The preferred training institution would give qualifications in science and in education

(4) Scientific and educational international organizations should catalyse the interaction of specialists to study the problems of integrating content at the B.Sc. level

In addition, the group on tertiary education listed the following three general considerations for teacher education in integrated science.

(1) To equip students leaving secondary schools adequately to face life if they prefer to discontinue their education and to form a sound background for those who pursue the university training

(2) To train teachers in integrated science would prepare them not only to teach integrated science at the various levels, but with the appropriate curriculum, they would be able to even conduct research in curriculum development

(3) Since integrated science as a subject should be based on the environmental and sociological conditions, rather than the classical aspects of science subjects, the person trained as a teacher of integrated science is bound to be a more useful member of the community than he is now.

Discussion of the summaries of goals of teacher education for integrated science at the primary, secondary, and tertiary levels

From the items reported, and the discussion which took place, it is clear that all three groups were concerned about the teachers' knowledge of the content of integrated science. As might be expected, the primary group modified this concern with the need for flexibility in design and approach of a program so a teacher would feel confident and competent to teach some integrated science even if his content background was quite limited. The tertiary group, at the other extreme, was so concerned about the question of content that they called for the interaction of specialists under the sponsorship of international professional societies to determine what is involved in integrating science at the B.Sc. level. One possible approach to the question of content preparation in integrated science is given in item 6 of the report of the secondary group. This question of content and competence is also related to the ideas expressed in the first and third general aims or goals reported by the tertiary group. The question is not just what content to include, but rather content for what. For further information and points of view on this specific question, the reader is referred to *New Trends in Integrated Science Volume II,* especially chapters 1, 2, 3, 5, and 9. From the reports and especially in the discussion, it became clear that all groups were extremely concerned about the role of the teacher in the classroom and his ability to present integrated science in a way that got across not only the subject but the spirit and approach which is science itself. In addition, there was considerable emphasis on the desirability of helping the student to see the relationship of science to his culture and environment and to help him see how he could use science to make decisions about and improve life for himself and his associates.

Although specific agreement on just what kind of science should make up integrated science (if there was to be any) at the upper secondary and tertiary level was not reached, nor could it be expected in the short time the group had to work together, the nature of the problem was defined to some extent.

Essentially, science at the upper secondary and tertiary level has at least two major goals. First there is the pre-professional and professional training of those who will become producers in the sciences and related fields. These individuals need specific knowledge and competencies, many of which are directly related to and/or are a part of the study of specific scientific disciplines. The second major goal is the provision of a knowledge, appreciation and understanding of science and the approaches of science for the entire school population at the upper secondary and tertiary level. Since the leaders of the local community and the country tend to come from this more highly educated group, the need for a knowledge of science and its possibilities and limitations, as applied to the problems of life, is most important. It is possible that the answer to the problem lies in the design of a program of integrated science as part of the general educational experience of all students at the upper secondary and tertiary level, with the study of specialized sciences and technology offered as a special elective or major for that part of the student population planing for careers in those fields.

THE RE-ORIENTATION OF SPECIALISTS FOR A ROLE IN THE TEACHING OF INTEGRATED SCIENCE

Report of Working Group Wg

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Rapporteur: Elaine W. Ledbetter, National Science Teachers Association, USA

INTRODUCTION

At all levels re-orientation is required in terms of (i) attitudes, (ii) skills and (iii) content, these three targets interact but the main task is to change attitudes.

The following types of specialists are identified as requiring re-orientation.

Elementary School

1. Subject specialist
2. Administrator
3. Supervisor, Inspector
4. Examiners, Evaluators
5. Parents, Community groups
6. UNESCO specialist

Secondary School

1. Subject specialist
2. Administrator
3. Supervisor, Inspector
4. Examiners, Evaluators
5. Support specialists: e.g. engineers, social scientists
6. Parents, Community groups
7. UNESCO specialist
8. Other subject teachers, e.g. mathematics, history

Teacher Educator

1. Subject specialist
2. Administrator
3. Supervisor, Inspector
4. Examiners, Evaluators
5. Support specialists: e.g. engineers, social scientists
6. Psychologists
7. Health educators
8. Special groups of engineers, medics, etc. overproduced by the local educational system

The chart (Figure 1) shows the personnel involved in retraining and how they are deployed. At the centre lies the pupil experiencing integrated science teaching and learning. Around him others who, in their different ways, provide the environment in which he works. The teachers have closest contact with the pupils and, in numbers and in needs, occupy most of the outer circle. Others who need to be informed and involved are shown in the figure but are separated by dotted lines indicating that their relative importance varies from community to community.

While needs and programmes would differ from level to level re-orientation would necessarily involve developing the following understandings, attitudes and skills.

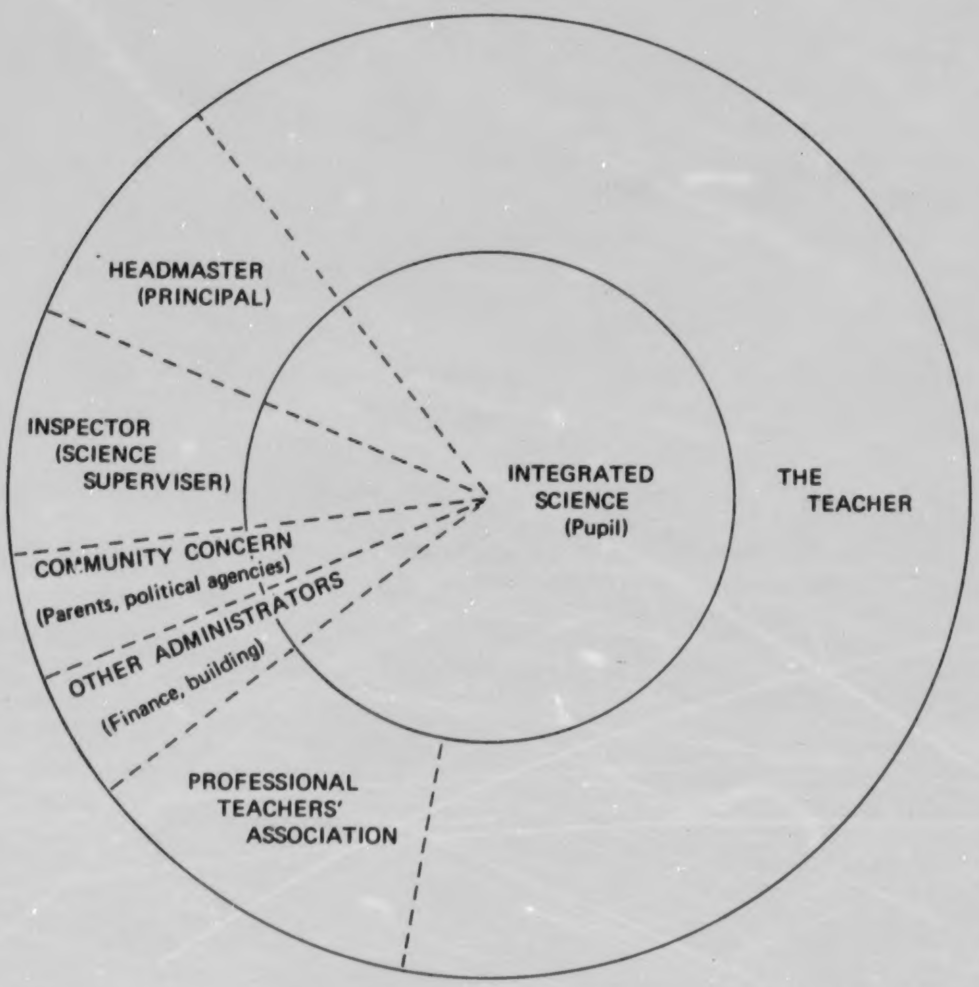

HEADMASTER
(PRINCIPAL)
INSPECTOR
(SCIENCE
SUPERVISER)
COMMUNITY CONCERN
(Parents, political agencies)
OTHER ADMINISTRATORS
(Finance, building)
PROFESSIONAL
TEACHERS'
ASSOCIATION
INTEGRATED
SCIENCE
(Pupil)
THE
TEACHER

Figure 1 PERSONNEL INVOLVED IN RE-ORIENTATION AT THE LEVEL OF THE ELEMENTARY SCHOOL

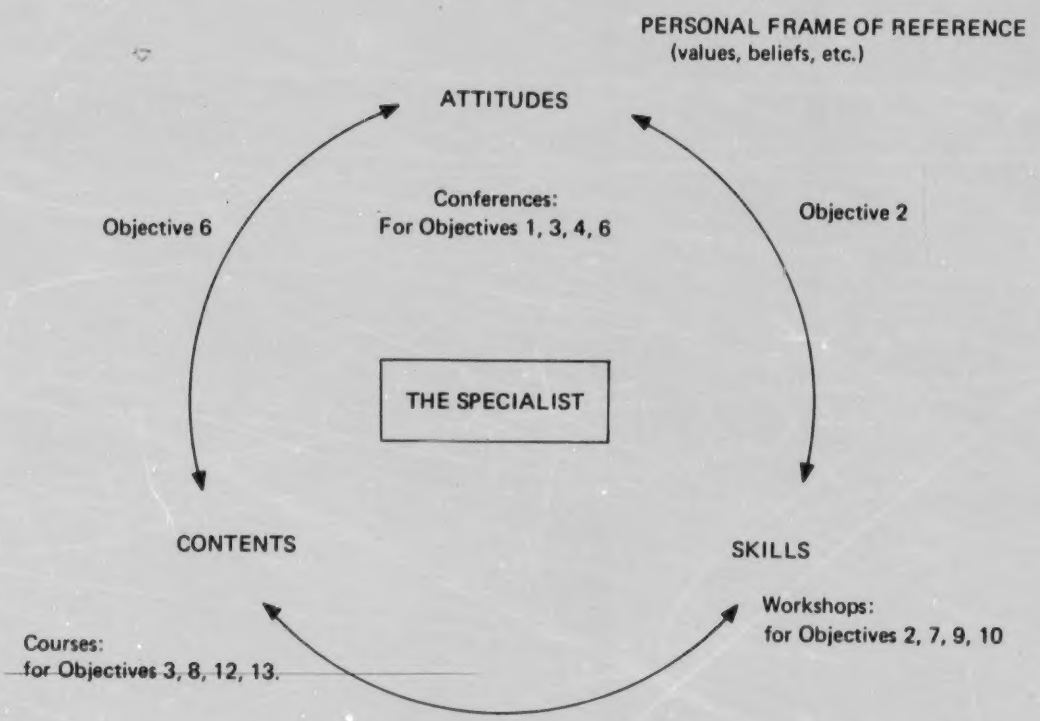
List of Objectives

1. An awareness of the 'process' dimension of science and its value in the school curriculum in contrast to the 'content' dimension.
2. Ability to view any approach to integrated science in the context of the total educational programme both horizontally and vertically.
3. Understanding, on the part of examiners, inspectors and supervisors, of the philosophy and objectives of integrated science curricula.

4. Willingness to accept the goals of integrated science in the context of one's own discipline.
5. Ability to formulate clearly stated objectives that can be achieved only through an integrated science curriculum.
6. Understanding and appreciation of the ultimate goals of science education.
7. Recognition of the limitations of one's background in a specialised area of science.
8. Sufficient knowledge of content in all areas of science for meaningful integration.
9. Skills in facilitating group dynamics, e.g. team teaching.
10. Skills in devising examinations appropriate for evaluating achievement in integrated science.
11. Skills appropriate for devising in-service programmes that can effectively achieve the retraining of specialists in ways that are economical in time and money.
12. Skills in constructing instruments for evaluating the success of retraining programmes.
13. Knowledge of available resources including human and environmental.

Programmes to bring about these objectives would, in general, involve conferences, workshops and courses of training. The following diagram (Figure 2) illustrates a generalized model of how such programmes of re-orientation could be interrelated. In all cases the starting point must be the personal frame of reference including the values and beliefs of the specialist.

Figure 2 MODEL FOR A PROGRAMME TO RETRAIN SPECIALISTS


PERSONAL FRAME OF REFERENCE
(values, beliefs, etc.)
ATTITUDES
Conferences:
For Objectives 1, 3, 4, 6
Objective 6
Objective 2
THE SPECIALIST
CONTENTS
SKILLS
Workshops:
for Objectives 2, 7, 9, 10
Courses:
for Objectives 3, 8, 12, 13.

RE-ORIENTATION FOR ELEMENTARY SCHOOL

At the elementary level of instruction the following kinds of specialists are of particular significance and require programmes of retraining.

1. Classroom teachers, who have general knowledge of all subjects, need to have greater depth of information in scientific disciplines to properly teach integrated science.
2. Administrators need an understanding of the goals of integrated science because they are responsible for setting policies that determine curricula.
3. Inspectors and supervisory personnel need to know enough about all sciences in order to guide and assist teachers in achieving the goals of integrated science.
4. Examiners need a thorough knowledge of science and integrated science curricula in order to construct evaluation instruments that are appropriate to the goals of integrated science at all levels.
5. Other specialists could include parents, community groups and UNESCO Specialists.

The following report has concentrated upon the re-education of a specialist in the teaching of pupils at the elementary level. This teacher is visualised as being deficient in science content background and having a limited teaching experience in the sciences.

In some countries there exist other types of elementary school teachers who might require a different kind of re-orientation than we have proposed. For example, teachers with a strong background in one or more of the sciences and with extensive teaching experience in science. Such teachers are likely to require a different kind of re-orientation experience.

Goals

As well as the general goals listed above, goals of particular importance for elementary specialists are as follows:

1. To develop (motivate) a teaching approach toward integrated science that uses scientific methods to gain new insights into knowledge through personal action of both the specialist and his pupils.

   To accomplish this goal, it is felt that a multiple activity approach should be followed. For example, the teacher should be given an integrated science course at a higher level than the course he will teach, but taught in a style analogous to the teaching he is expected to utilise in his own classroom. Either simultaneously or in a second course the teacher should have the opportunity to compare, evaluate and contrast the strategies and the content of different kinds of integrated science programmes written for the elementary level. In addition to these studies, the teacher should be educated to identify and actually perform the experiments unique to these varied programmes. These experiences will provide the teacher with new methods, materials and techniques that can be adapted to his own teaching situation.
2. To acquaint the teacher with the processes (methods) which scientists use.
3. To develop a working concept of the nature of science.
4. To inculcate the spirit of enquiry into daily teaching procedures.
5. To apply enquiry methods in teaching through many laboratory experiences.
6. To develop such practical skills as:
   (a) recognition of variables in a system

(b) gathering and interpreting data
(c) identification of science problems
(d) initation and continued use of activities directed toward problem-solving
(e) the creation of a learning environment in which curiosity and creativity are fostered
(f) increasing the elementary teacher's competency in science content in three major areas: the subject matter related to that which they teach, the relationship between different approaches to content organisation, and the philosophy and strategies of different integrated science programmes.

This kind of programme in integrated science for the elementary teacher must be flexible in such a way as to encourage improvisation of new materials for use with pupils.

Programmes and Activities

(i) *Re-orientation of Headmasters (Principals) and Inspectors (Science Supervisors)*

Goal: to familiarise the school administrators with integrated science materials in order that they will support the individual teacher in the implementation and continued use of integrated science materials.

To accomplish this goal, orientation meetings, seminars, workshops and conferences of short duration should be held with the administrators. In these meetings the goals of integrated science programmes should be presented. Details related to equipment and teacher support are also to be included in such meetings.

Experience has shown that school administrators respond favourably to the loan or free distribution of materials and equipment during the testing period of a new programme. This kind of support is needed to build confidence in the programme and to provide prestige to schools using integrated science courses for the first time.

(ii) *Re-orientation of Other Administrators and Community Groups*

Goal: to familiarise these groups with integrated science materials and to enlist their support in accepting the programmes.

To accomplish this goal a series of short meetings with parents, politically influential groups and others should be designed to bridge the communications gap between those advocating the integrated science programme and these diverse groups. It is essential that these groups understand the broad goals of integrated science and do not become too time-consumingly involved with the specific details of the programme.

Evaluation of the Re-orientation Programmes

During the training of the elementary teacher in integrated science the instructor should maintain a continuous evaluation of his instruction by observing the behaviour of those taking the course. The behaviour of the participants should be consistent with the objectives of integrated science.

After completing the course a multiplier effect can develop if the teacher organises and teaches his own colleagues. The in-service course might be in the form of a simulation of the actual classroom situation and can provide for group evaluation of the programme.

As the course is being taught in the classroom an evaluative investigation might be carried out. Suggested procedures are listed as follows:

1. Feedback meetings involving all teachers using the materials.

2. Attitudinal surveys should be given to both the teachers and their pupils.
3. Classroom observations should be conducted by those responsible for the training programme.
4. Achievement testing of pupils should be conducted on a regular basis.

RE-ORIENTATION FOR SECONDARY SCHOOL

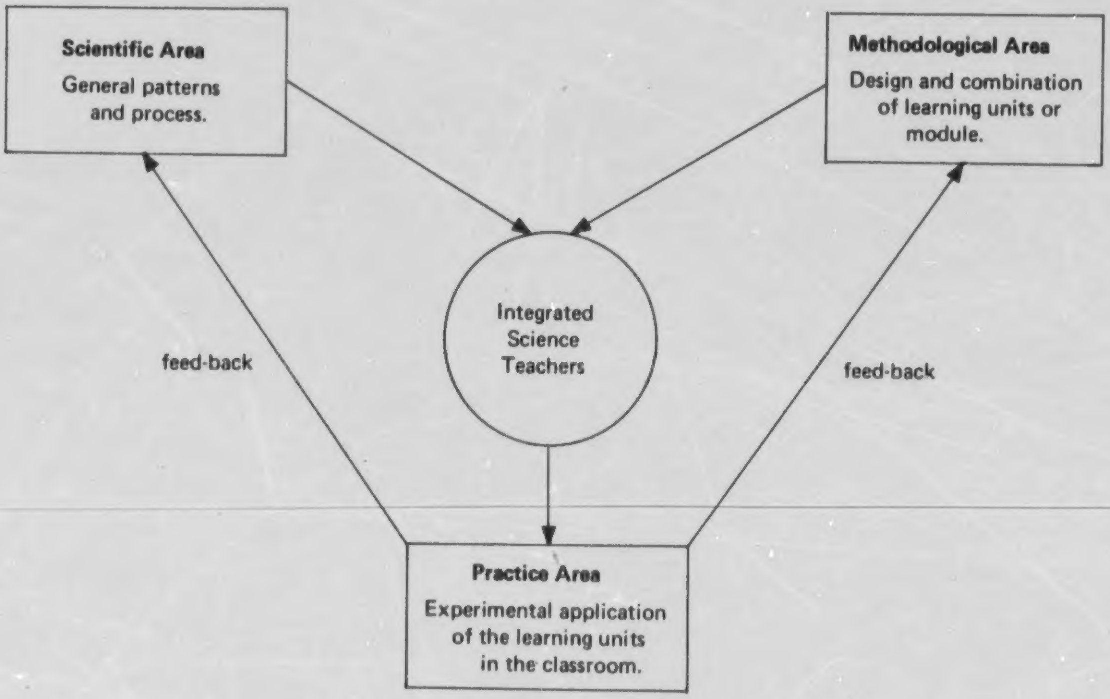
Secondary specialists who need to be retrained fall into the following categories: subject matter specialists, administrators, senior teachers (department chairman) and supporting groups such as examiners, health science experts, and psychologists. UNESCO specialists, parents and others may also be considered as specialists.

Subject matter, discipline-oriented teachers are important because of the specialised knowledge they bring to integrated science. Their retraining should broaden their sphere of knowledge and also change their concept of science from content alone to process. Engineers, mathematicians, psychologists, health specialists and administrators can be useful in helping to develop new curricula.

Organisational Format:

The following chart (Figure 3) shows the relationship that exists among the scientific areas, methods of teaching and actual practice and the influence of each upon the retraining of a secondary specialist to understand integrated science.

Figure 3 RELATIONSHIPS: SCIENCE, TEACHERS AND METHODS


Scientific Area
General patterns and process.
Methodological Area
Design and combination of learning units or module.
Integrated Science Teachers
feed-back
feed-back
Practice Area
Experimental application of the learning units in the classroom.

Relevant Needs and Problems

The most basic need in re-orienting secondary specialists is the need to alter existing attitudes and educational philosophy. Subject matter or discipline-oriented teachers need training that will enable them to change their basic philosophy so that they may view the teaching of science as a melding of all separate disciplines into a whole. This will involve also providing content material in the disciplines in which the specialist is weak or totally deficient. In some cases new methodology will need to be acquired as well as new laboratory skills.

Programmes and Activities

One activity that can assist the secondary specialist to become oriented toward the teaching of integrated science is team teaching. By using this approach teachers who are specialists in one area can help those who are specialists in different areas by sharing knowledge, skills and techniques. This can occur both inside and outside the classroom situation.

Under the direction of a university specialist or another teacher specialist, teachers may engage in mini-research projects in a field outside their own speciality. By so doing they can gain insight into other areas of science by engaging in laboratory based enquiry oriented activities that will extend their knowledge. Short courses in content provided by colleges and universities either in the summer or as evening sessions during the school term can serve to bridge gaps in content areas. In addition, some teachers may feel the need to take longer courses that go into greater depth.

It is important that teachers be able to interact with other specialists in a horizontal way. That is, in a group discussion with other specialists there can be two-way give and take with each participant learning from others. There may also be a vertical interaction between a specialist and a group of teachers who are striving to learn a discipline not familiar to them.

Consultancy assistance as teachers are working, visits to schools already teaching integrated science and in-service activities planned to meet the specific needs of the teachers participating can be of infinite value in retraining teachers.

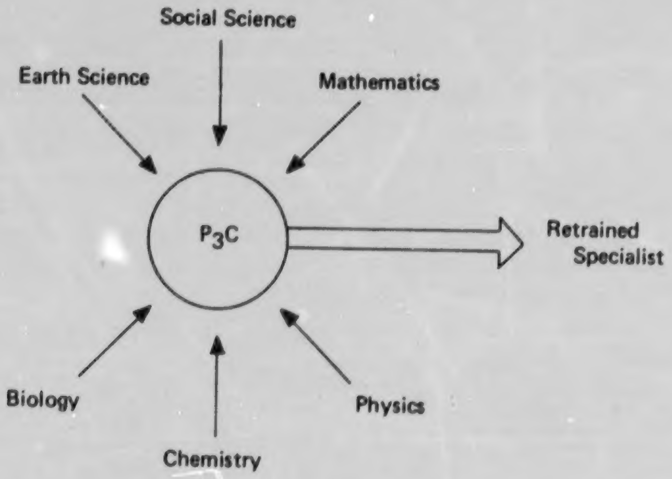
Scholarships and other forms of financial aid may serve as added incentives for secondary specialists to participate in retraining programmes of the kinds described.

Evaluation of the Re-orientation Programmes

In considering the construction of evaluation instruments we must be cognizant of the goals of integrated science teaching. The secondary specialist should be given an opportunity to acquire content material from all sciences. In addition to this, he will need to acquire an understanding of the problems, processes, phenomena and concepts in the various disciplines. These factors should be included in the evaluation of his training programme. The following chart (Figure 4) provides a method of viewing the importance of these factors.

Evaluation may be undertaken by students, colleagues, or supervisors, and may use standarized tests, observational techniques and other strategies. The effectiveness of the personnel conducting the retraining should also be evaluated.

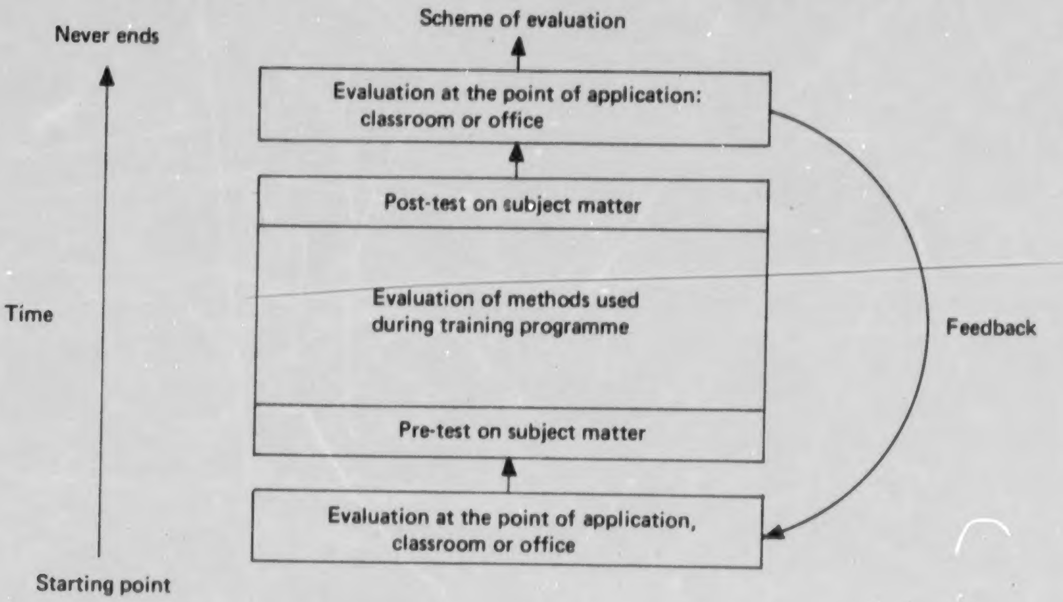
Figure 4 FACTORS IN THE EVALUATION OF A TRAINING PROGRAMME


Social Science
Earth Science
Mathematics
P_3C
Retrained Specialist
Biology
Chemistry
Physics

P_3C

1. Problems (pollution, population, food, etc.)
2. Phenomena (light, matter, etc.)
3. Processes (modelling, etc.)
4. Concepts (symmetry, relativity, etc.)

Figure 5 A GENERALISED SCHEME FOR AN EVALUATION PROGRAMME


Never ends
Scheme of evaluation
Evaluation at the point of application: classroom or office
Post-test on subject matter
Time
Evaluation of methods used during training programme
Feedback
Pre-test on subject matter
Evaluation at the point of application, classroom or office
Starting point

RE-ORIENTATION FOR TEACHER EDUCATION

At the level of teacher education, specialists requiring re-orientation include subject specialists, administrators, supervisors and inspectors, examiners and evaluators, support specialists, psychologists and health educators. A particular problem at this level is the rather large number of engineers, medicos and other specialist groups that may have been over-produced in certain local educational systems and who have moved across to the teaching profession. Another type of person requiring re-orientation is the teacher with a good background of teaching experience but with the little or no background in science.

Programmes and Activities

The following types of programmes are specifically recommended for this level of training.

1. Short in-service orientation courses, preferably followed by a suitable follow-up programme.
2. Activities for group seminars and discussions, teachers' clubs, and science centres.
3. Production of 'teaching materials', including background readers and teachers' guides, to be introduced in long courses at the university/teacher training institutes.;
4. Production of unit concept science films in an integrated way. These films, generated for student teachers as well as for the lay public, to be screened on TV wherever possible.
5. One-year or six months retraining courses in the philosophy and methods of integrated science to be conducted by universities and colleges. Support for this through the award of scholarships should be encouraged.
6. Programmes of educational visits to schools with successful courses of integrated science and to various industries which play key roles in the economy.

Evaluation of Re-orientation Programme

Evaluation of re-orientation programmes for teacher education could be at three levels:

1. self evaluation by the teacher educator
2. evaluation of the teacher educator by his colleagues
3. evaluation of the teacher educator by his students

In each case relevant and appropriate changes in reading, speaking and practical activity should be noted and such changes be used to infer overall attitudinal re-orientation. Specific observations might be made of the following:

(a) assessment of reading habits, perhaps through library records

(b) assessment of oral skills using various modifications of Flander's technique

(c) assessment of way the laboratory activities are organised

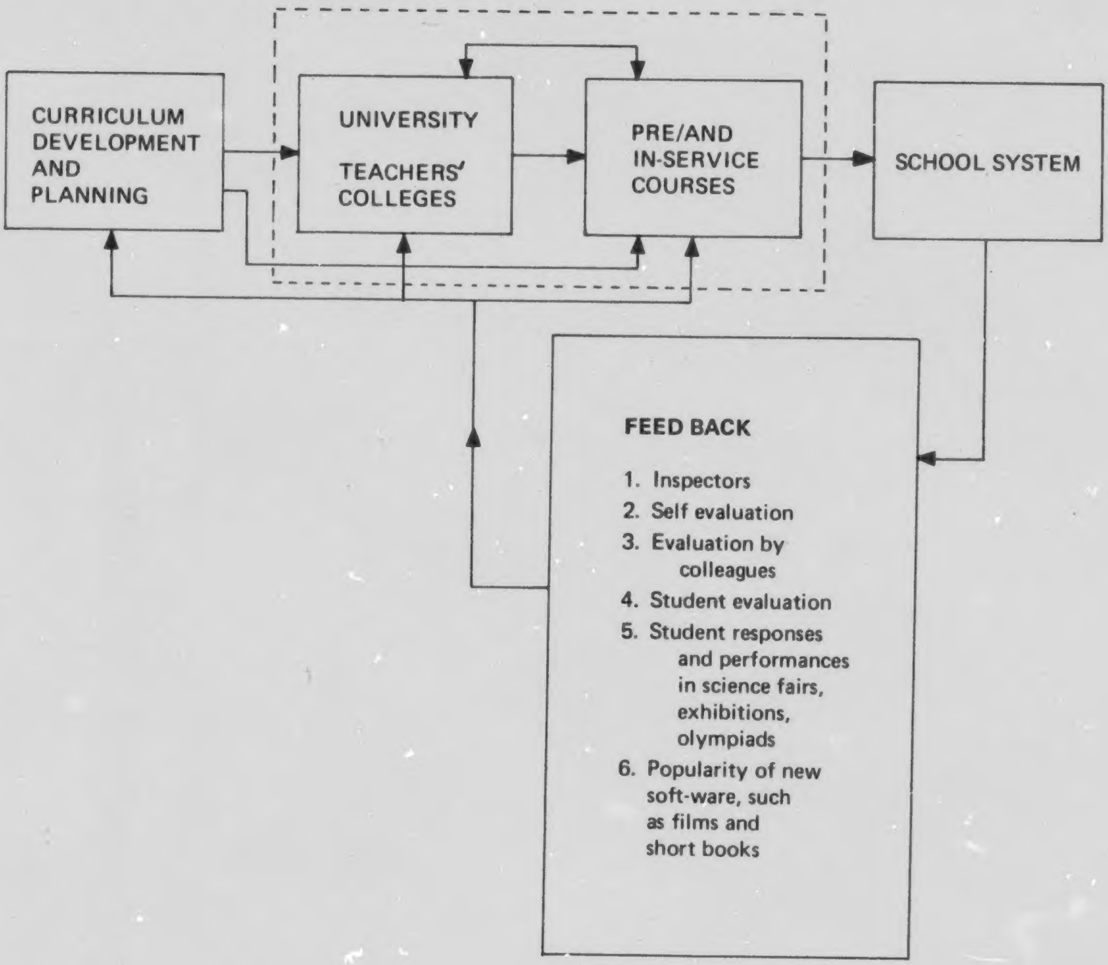
Assessment of effectiveness of the re-orientation should involve evaluating aspects of the *product* of programmes of teacher education – namely the relevant attitudes and skills of the newly qualified teacher of integrated science produced by the re-orientated teacher educator. Those skills that could be assessed include:

1. Ability to plan integrated science units.
2. Ability to translate integrated science programmes into action.
3. Ability to produce materials for teaching integrated science.

4. Ability to use scientific processes such as making hypotheses, experimenting and collecting and interpreting data.
5. Awareness of the relationship between science and life in general.

A general model for this type of evaluation is given in the following diagram. (Figure 6).

Figure 6 A MODEL FOR EVALUATING RETRAINING PROGRAMMES FOR TEACHER EDUCATORS FOR INTEGRATED SCIENCE


CURRICULUM DEVELOPMENT AND PLANNING
UNIVERSITY
TEACHERS' COLLEGES
PRE/AND IN-SERVICE COURSES
SCHOOL SYSTEM
FEED BACK
1. Inspectors
2. Self evaluation
3. Evaluation by colleagues
4. Student evaluation
5. Student responses and performances in science fairs, exhibitions, olympiads
6. Popularity of new soft-ware, such as films and short books

This is not a once-only programme. It is continuous and regenerative and should build up, slowly at first, but hopefully, quite rapidly later.

CASE STUDIES OF RE-ORIENTATION

Delegates reported on the following examples of re-orientation programmes or activities from their respective countries.

Argentine Republic Curriculum in primary schools includes integrated science and primary school teachers are given short in-service courses related to the curriculum. Such retraining programmes are described in 'Proceedings of the Seminar on Chemistry Teaching' UNESCO, Montevideo, July 1972.

Australia Macquarie University (Sydney) provides a training course 'A View of Science' for undergraduates. This is interdisciplinary in nature and includes topics such as 'Social Origins of Science', 'Science and the Future' and 'Light and Atoms from 1800 to 1826'. This type of course has proved useful in re-orientation of teacher trainees.

Colombia The Ministry of Education provides a programme of consultation on the various areas of science for secondary school teachers. Stress is given to methods of teaching, educational technology and techniques of evaluation. While integrated science programmes have yet to be introduced, the present in-service programme would provide a suitable model since the aim is to produce a multiplication effect. The re-orientated secondary school teachers will in turn be required to train primary school teachers.

Czechoslovakia The Ministry of Education organises in-service summer courses through the universities. In addition, in each school a committee of about ten teachers plans programmes and makes recommendations for within school seminars. Sometimes these involve staff from more than one school. With regard to evaluation considerable stress is placed on student evaluation of courses.

Denmark At the new Danish universities in Roskilde and Odense two different introductory educational programmes are being developed. Each is a two years' introductory basic course including several sciences, contrary to the traditional university education which does not allow physics and chemistry studies in combination with biology and geography. In Roskilde very untraditional teaching methods based on various forms of group activities are being used. In Odense the teaching methods are of a more traditional kind.

A consequence of the untraditional contents of the basic programmes will be new combinations of the sciences studied in the more specialised education on top of the basic course.

Probably science teachers educated in the new way will find it easier to co-ordinate the teaching of physics, chemistry, biology and geography in the Danish senior high schools. Also, they may be easier to deflect toward the teaching of integrated science if it should be found adequate to introduce integrated science in the Danish senior high school.

Ghana The Science Education Programme for Africa (SEPA) with Secretariat in Accra has had success in the re-orientation of the specialist. This has been achieved through the development of special teacher education materials, by conducting regional in-service teacher training meetings and through the programmes of Science Curriculum Development Centres in various countries and of the newly established Centre for Educational Evaluation in Africa (at Ibadan University Nigeria).

Further information on the work of SEPA is available from SEPA Secretariat, Box M-188, Accra, Ghana.

India Some State departments of education provide periodical in-service meetings for teachers involving about 15 days every three years. Many Ph.D graduates enter the teaching profession and these students are given re-orientation programmes.

Italy The University of Palermo has undertaken an experiment in the in-service education of secondary school teachers. In-service courses have been introduced consisting of weekly meetings of teachers, scientists and psychologists, combining interdisciplinary seminars, general discussions, and group work on specific subjects. These courses have proved successful in developing favourable attitudes towards interdisciplinary education.

Mexico In-service programmes offered by the Consejo Nacional para Enseñanza de la Biologia since 1970 stress upgrading of content and improvement in methodology of current courses. Interdisciplinary programmes have not so far been introduced but a suitable mechanism is available for the introduction of such programmes.

Nigeria The Advanced Teacher Training College, Owerri, Nigeria, provides a programme on the teaching of integrated science to pre-service teachers who will specialise in the teaching of one or two of physics, chemistry, biology, maths, physical and health education, agricultural, home economics.

The objectives are

(a) to give the student teachers a broad science background prior to specialisation

(b) to make them competent to teach integrated science when they eventually start teaching in secondary schools

Methods used include:

(i) Involving students in developing the curriculum

(ii) team teaching

(iii) discussion amongst teams

(iv) evaluation by colleagues

Peru An experimental course of integrated science for elementary school teachers has been developed under the direction of Professor Cesar A. Quiroz. This is the Programa Nacional para el Mejoramiento de la Enseñanza de las Ciencias – PRONAMEC – P.O. Box 3845, Lima, Peru. Re-orientation is achieved by means of new learning materials, by consultancy services for teachers using the materials and by special in-service programmes sponsored by the Ministry of Education and by external founding agencies such as USAID-IPFE and UNICEF.

Philippines Republic Science Centres, inter-school links and in-service courses run by universities play a role in the re-orientation of specialists. There is considerable interest expressed by teachers in improving themselves academically as this leads to improved status and salary. In all training programmes emphasis is given to student evaluation of the teacher and teachers are graded according to these evaluations.

Spain A long course is now made available by the Ministry of Education for primary school teachers seeking promotion to junior high school teachers. This course includes information about the co-ordinated areas of science.

Trinidad The integrated science programme for the junior secondary schools of Trinidad and Tobago WISCIP (West Indian Science Curriculum Innovation Project) has re-orientated specialists through the production of detailed teachers' guides. The guides are divided into units. Each unit includes a discussion of its significance and objectives, the background knowledge assumed and references, a list of materials required, in addition to a series of Activities. An Activity represents the work of one or sometimes two periods, and in addition to specifying objectives and detailing the materials and preparation required, detailed guidance on teaching method in provided. This guidance extends to advice on how to introduce an activity, how long to spend on various parts of it, important questions to ask and responses sought from the pupils. The activities cover a wide range of teaching situations both in the classroom and laboratory: demonstrations, pupil experiments, circuses, observational exercises, information gathering, as well as outdoor activities, home work and tests.

United Kingdom Three developments were reported:

(i) At the University of Surrey, Guildford, Surrey, there is to be a four year programme fusing physical sciences and science education.

During the first and second years, the course is at the University and concentrates on the teaching of the subject, and in the third year the student receives his professional teacher training in the College of Education. This includes a substantial amount of school practice, which should show up the difficulties the student has in understanding what he is expected to teach. This in turn should provide the motivation for the final year, when the student is back at University and concentrates on science studies and science education.

A case is made for students of this type to study science in an integrated form and this requires subject specialists who will teach him in an integrated form. At present these hardly exist, so that a course in the physical sciences tends to be taught by people some of whom think of themselves as physicists and some as chemists. Ideally, these should re-orient themselves to become physical scientists, but until this happens, the answer must be team teaching.

(ii) The Nuffield physical science project has successfully re-orientated teachers of physics and chemistry for teaching integrated physical science through in-service activities and team teaching.

(iii) Her Majesty's Inspectors in the United Kingdom visit schools and offer a consultative and advisory service on integrated science, identify areas of need for in-service courses and recommend the development of learning materials and resources that would assist in the re-orientation of the specialist.

The United States of America Two projects were reported:

(i) The Humanistic Approach to Elementary Science Teaching is a project in integrated science based at Allentown College, Center Valley, Pa. This project has certain aspects relating to the re-orientation of the specialist. For further information see entries in the International Science Education Clearinghouse Report (1972) under HANS and ESTT.

(ii) Federation of Unified Science Education (FUSE) through the Centre for Unified Science Education (CUSE) at Ohio State University has activities for the re-orientation of the specialist. These include the following:

  (a) Assembles and maintains resources useful to working groups from local school systems exploring and/or implementing unified science programmes.

  (b) Conducts intensive workshops to achieve re-orientation of science teachers toward unified science education.

  (c) Conducts specially designed workshops and short courses intended to re-orient supervisors and administrators.

(d) Produces and circulates a quarterly publication to facilitate achievement of general goals of Centre.

(e) Provides models for unified science curriculum development.

(f) Provides consultation with school groups upon request.

DISCUSSION AND COMMENT AT PLENARY SESSIONS RELATING TO INTEGRATED SCIENCE AND THE INTEGRATED SCIENCE TEACHER

Overlying much of the discussion about the training of teachers for integrated science teaching lay the doubt as to just what we mean by integrated science. In order to proceed with the purposes of the conference, that is to discuss teacher training, the following definition of integrated science was accepted by the working groups so that they could make progress in their major task of discussing the training of teachers.

Integrated science has been defined as those approaches in which concepts and principles of science are presented so as to express the fundamental unity of scientific thought and to avoid premature or undue stress on the distinctions between the various scientific fields.

The definition stresses approaches rather than content and this is perhaps the most significant distinguishing feature of integrated science teaching. There is no doubt of the increasing interest in integrated science throughout the world. There can scarcely be a single science course at the elementary level which is based on discreet, separate science subjects. At the lower secondary it is probably true to say that the majority of children studying science do not go to special classes for physics, chemistry, biology, geology and other specialist sciences. At the upper secondary levels the problems are greater; nevertheless integrated science is slowly gaining ground and at even higher levels a number of universities, polytechnics and teacher training institutions are experimenting with integrated science, most frequently with non-science majors but increasingly with students who might otherwise have chosen single science courses.

Today, more and more project leaders preface their suggestions with lists of aims and objectives and then select the activities and the content with these in mind. The aims of integrated science teaching cannot be achieved by merely bringing a few separate subjects together, especially if this only means following a session of biology with one of chemistry and one of physics. Integrated science cannot be approached meaningfully without reconsidering one's whole teaching philosophy. Most projects today play down the syllabus and work far more on teachers' guides and materials which exemplify an approach determined by aims and objectives. This is where difficulties arise. It is very easy to construct a new syllabus. It is much more difficult to define a teaching style and even more difficult to ensure that teachers adopt the style in the way intended. W. Hall noted that teacher trainers face an awesome task. So many of the objectives which we write down deal with changes of attitude. These attitudes are often deeply engrained and to ask the teacher to change a large number of them is optimistic. Hall felt that the key to changing attitudes is to provide resources and opportunities for teachers to become confident in their teaching. Once confidence is achieved attitudinal changes can follow. For this reason positive concrete help is required by teachers and by those helping to train them.

K. Dowling was keen that integrated science be based upon a solid rationale rather than intuition. He saw confusion in the minds of many advocates of integrated science teaching today and if similar confusion exists in the minds of those responsible for the training of teachers then widespread acceptance of the new themes will be difficult to accomplish. Programme objectives must be based upon the commonalities of science, and exponents of integrated science teaching must recognise just what these are. He mentioned that science can be recognised by its common conceptual schemes, the process structures, the nature of science and the scientific endeavour, its cultural and social implications. All these attributes of science need to be specified and incorporated into courses for schools and made explicit in courses of teacher training. Another speaker distinguished unity and multiplicity, the former being concerned with relationships and links, the latter with separate facets of a problem or area of study. He called for a multiplicity of approaches within a school, depending on a teacher's personal interpretation of the needs of a class but unity in the subject matter.

R. Meyer recalled that hierachies of objectives have been created for many areas of study in school and college. He felt that the production of such a hierarchy is a valuable exercise but that it is the activity and discussion involved in producing the hierarchy which offer most. The acceptance of a hierarchy defined by others is less satisfactory. The transfer of hierarchies of objectives across cultures is particularly dangerous. The objectives of science teaching in a rural country may be quite different from those in an industrial country. Even within an industrial country the objectives may vary from area to area. One area may have substantial chemical industries, many fathers and relatives will work in these factories and many boys, and girls for that matter, may subsequently work in the chemical industry. The interest pervades the community and even those who will not have direct vocational interests in it will nevertheless gain from studying the particular chemistry of the area in some depth. In other areas it may be the motor car industry, in others electronics or pharmacy. In rural areas crop yields, fertilisers, irrigation, weather forecasting, methods of distribution and the social implications of setting up co-operatives to distribute the produce are all areas which merit scientific study. Again the needs of the community, the interests of the community, will vary from country to country, from region to region.

There need be nothing permanent about a hierarchy of objectives. Not only will local needs change but also local possibilites. A new laboratory, an influx of more skilled teachers, the arrival of an electricity supply, even a change in governmental policy may cause a reconsideration of aims and objectives and a re-appraisal of the hierarchy. Sometimes today an edict from an administration changes things without involving or clearly explaining to the teachers what it is that is happening. Other quite concrete factors can also change the teacher's priorities without him realising that the changes are taking place. The range of objectives needs to be appropriate to the conditions and it needs to be clearly expressed so that teachers can study the hierarchy, understand it and act upon it – even if necessary reject it, to suit their own circumstances.

The creation of integrated science teachers from those who had been successful specialists for many years was seen to be a difficult issue. The in-service training discussed in Part 3 of this volume is important here and as A. Touren explained solutions will be most difficult to find in countries where specialisation in school is commonplace and takes place at an early age. At secondary level in France, education in physics and chemistry has always been carried out by the same teacher and this makes it easier to integrate these two areas. Biology, however, is more difficult. Many teachers of physics and/or chemistry have not studied biology in any great depth and at the higher levels especially it will be very difficult for them to achieve a level of biological knowledge and understanding equal to that of their physics and chemistry. In this way bias will inevitably creep into their teaching. Most participants at the conference felt that full integration across the whole range of possible science studies would be difficult at the higher levels; e.g. the university or polytechnic. Others felt that at school level we ask children to tackle not only two, three or more sciences, but also perhaps their own local language, two foreign languages, mathematics, history, geography, religious knowledge, a whole host of quite unfamiliar areas of study. Some thought that it is not too much to ask a teacher, highly qualified in one or two specialisms, to study a third to an adequate level for worthwhile work to be done with children. In addition if the children look to the teacher as a provider of interesting questions, rather than a provider of highly accurate information, then the teacher's needs in terms of knowledge are less. It is, however, unrealistic to ask a teacher with *no* knowledge of a topic to lead discussion and experiment effectively. Specialists need some knowledge of all subjects but they also need to be re-organised in terms of their thinking. There are differences in the ways biologists, chemists, physicists, geologists, astronomers proceed, and these need to be made explicit, not in order to differentiate between them but to see what they have in common whilst still recognising that different procedures, different levels of confidence, different styles of laws and different probabilities, exist amongst these various branches.

R. de Llopis Rivas was concerned about the lack of mathematical interest amongst biologists and she was concerned that the re-orientation needed by a biologist at the higher levels, to encompass the theories of the physics-style topics was considerable. Certainly special training would be required for many biologists to cope with such materials. C. A. Taylor however felt that schoolteachers do not always know the extent to which integrated work is at present carried out in the universities. It is often the smaller universities and colleges which do this and there are courses linking medicine, biology, music, biochemistry, the mechanics and cybernetics of machine tools etcetera. Taylor strongly recommended teachers to seek out their local university or college and to see what integrated work is in progress in research and or in teaching.

The fear of mathematics may be one reason why biologists are sometimes unwilling to consider integrated science teaching. Where there are experienced teachers, highly competent in their own specialism, and yet unwilling to change, innovation must look to the young teachers who offer the greatest hope for introducing the new teaching styles. The older teachers should be encouraged to retire if they are unable to cope with integrated science. Innovation can be seriously damaged by teachers who are compelled to tackle new ways and new content and do it without conviction. As G. Ramsey indicated so clearly, imaginative schemes can easily be killed by hostile teachers or at least severely injured by unsympathetic ones.

As in so many of the discussions, the question of insecurity, even fear, on the part of a teacher asked to tackle materials with which he is not familiar was raised. Again and again the question of increasing confidence was stressed. L. Baggerly discussed three stages in the process of re-orientating subject specialists to integrated science. First they must be initiated into the mysteries of the other subjects, second they need support whilst they experiment with the teaching of these subjects, and finally they need to grow to the stage where they can develop new teaching schemes. Baggerly called for some clarification of the different needs of these three stages, He asked what each stage entails for the teacher, and indeed for the teacher trainers concerned with in-service training. It was thought that science educators and researchers might have a role to play here. Entering schools or colleges with the intention of looking critically at what is going on, researchers could ask questions which would act as a very first initiation into the new thinking. But for this to be effective the barrier between teachers and researchers needs to be lowered substantially. Each group needs to see the other as a partner and each needs to respect the opinions and the findings of the other.

C. Saturn asked whether the researchers have developed any theories relating to the kind of activities in which teachers should engage to bring about a change in attitude, for it is a change in attitude which is required rather than a change of knowledge. Re-orientation courses, or meetings which are basically informational, to which biology experts contribute their biology knowledge, physics experts their knowledge and chemists theirs, are unlikely to be effective. There is anecdotal evidence to this effect but the research findings and the theories which could explain this failure are lacking.

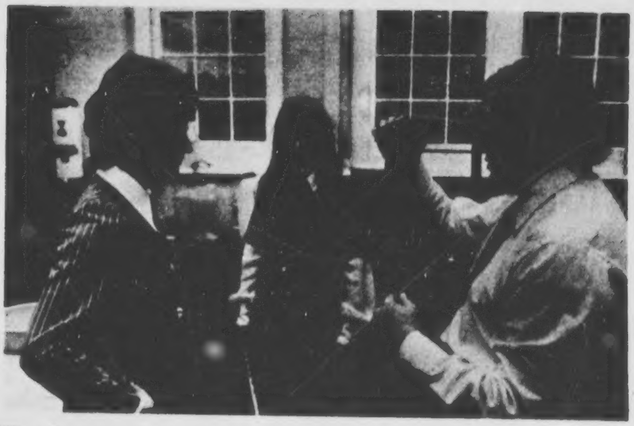
Again the discussion came back to the view that the changes which need to be brought about are changes in the heart, not merely changes in the head. R. de Llopis Rivas felt, however, that an intellectual understanding of certain aspects of educational theory would help a teacher to cope with current innovations. There are aspects of learning theory and communication theory which support our procedures and already educational technology is supported by a substantial volume of research. Research and information in these areas could usefully be reported to teachers on courses. In this way the head could justify the changes of heart. It is important not to underestimate the ability of teachers to cope with the theoretical justifications of their procedures. So long as teachers accept edicts from above without thought or due consideration, so they will often tend to drop back into a defence of their existing position. Courses in educational theory offer opportunities for informal discussions where teachers can talk about their fears and difficulties in a context other than that of subject knowledge. When fears are eased, the tackling of new subject matter becomes less disturbing and if the educationists have done their job well, could become an existing challenge.

K. Keohane raised the question of science within the whole curriculum. Already, at the elementary level, there is substantial experience of children taking part in an 'integrated day' where a casual observer would detect no particular subject, where children may be experimenting, writing, drawing, calculating, playing, in an apparently unorganised way. In such a situation the teacher has a huge responsibility to ensure that the children are all usefully engaged and that they do cover areas of human activity which are generally acknowledged to be valuable. The native language and basic mathematics are universally accepted as desirable components of any elementary course, integrated or not. Many of us would like to see scientific investigation become another required component of an integrated day. This is not to say that subjects will come in, but that the perceptive teacher arranges for investigations to be on hand and ensures that at some time every child takes part in something scientific. The demands which such an approach makes upon the teacher are substantial and she does need the maximum support in her attempts to integrate science with the rest of the curriculum. The very best of these teachers take science in their stride. They take as their teaching brief the whole environment of the child, intellectual, aesthetic, social, and tackle any problem which comes their way. Nevertheless, it is always useful for a teacher, however imaginative, to have some knowledge of the areas under consideration. In fact, it was easier to work through a text book, keeping one chapter ahead of the children, than it is to provide them with a stimulating environment and allow them to ask questions about it and to devise experiments to investigate it.

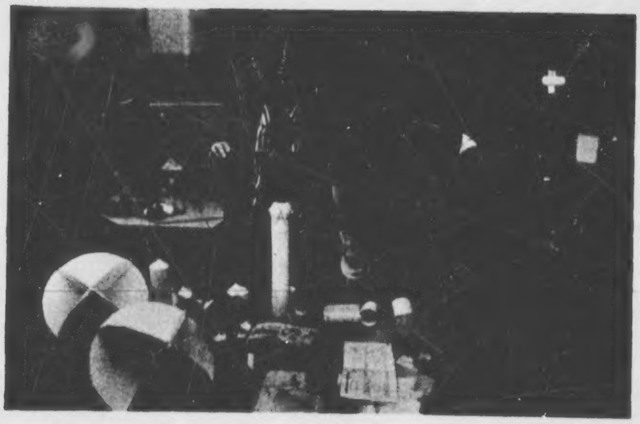
This section has been concerned with discussion about integrated science and the teacher. Nowhere during the conference has the position of mathematics been discussed in detail. Nevertheless, many speakers were disturbed that mathematics was not under discussion. One or two participants felt that mathematics and physics were more akin than, for example, physics and biology, and in many cases the absence of mathematicians was regretted. In fact, there seems to have been disappointing progress in integrating mathematics courses with science courses. Perhaps the next stage in the integration process will be the consideration of areas larger than integrated science or combined history and geography, or tentative attempts to combine humanities. Perhaps the next stage will be schools running in perhaps three or four faculties rather than in particular subjects.

Part 2

The Pre-Service and In-Service Education of Science Teachers



Planning



Making

Testing

Plate 2. All the pictures were taken at a course held at the Curriculum Development Centre, Southampton, U.K. People involved include graduate students attending an initial training course, experienced elementary school teachers, a science adviser and a University lecturer.
(Photos: Alan Hayward)

THE PRE-SERVICE EDUCATION OF TEACHERS OF INTEGRATED SCIENCE AT TRAINING COLLEGES AND UNIVERSITIES

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The present paper may be considered as complementary to Dr. Ramsey's contribution. Both our papers should be read in the light of our common conviction that the initial and the continuing education of the teacher form a whole and cannot be considered in isolation.

In the paper that I wrote for you before the conference I quoted an extract from that delightful little book by Alec Clegg titled *The Changing Primary School.* [1] The changes that have been seen over the years in the English primary schools are brought alive by the collection of essays which Clegg has brought together in this book. He recalls how in the latter years of the 19th century teachers were still faced in England with a policy of payment by results; classrooms were extremely formal in their arrangement and the curriculum was geared largely to mechanical processes in the three R's. Whan an enormous change can be seen today, and of course the teacher and his training are central to these tremendous improvements in the learning approach that has been achieved with young children.

For the past several years, I have personally been concerned with Direction of the Nuffield Foundation Science Teaching Projects, which, together with the Schools Council Projects have given some lead towards the development in the United Kingdom of curriculum materials firstly in the individual sciences and more recently in the field of integrated science.

Several of the project developers are attending this conference. Hilda Misselbrook and Bill Hall have been concerned with the development of materials for the secondary teacher of the middle-school years, 13 – 16 age range (Nuffield Secondary Science and Schools Council Integrated Science). Maurice Elwell has been responsible for another form of integration, the 'Nuffield Combined Science' materials for use in the junior secondary years (11 – 13 years).

John Spice has been concerned with the integration of physics and chemistry into a physical science programme in the upper school years, which in some instances is applicable also to the early years at university. Others here have been concerned with the implementation and training of teachers for these schemes of study. We also have Elizabeth Williams, who was putting into practice many a year ago those approaches which so many of us sometimes claim to be new. This is an important point to be remembered, and I was delighted to find the two words 'new approaches' omitted when the final programme of this meeting was drafted. Much of what is now being encouraged has in fact been the method used for a very long time in what are sometimes called 'progressive' circles, and now we are saying that the flexible approach to learning which in the best circumstances already exists in the classroom should be extended to teacher education. But before this can be considered we have to look at the experience and background of the student whom we are starting on the road to be a potential teacher.

By and large, in all our countries we are taking students from schools with very varied educational and social backgrounds, particularly when we are concerned with the education of the primary teacher. Intellectual abilities are not to be disregarded but other qualities go towards the making of a good teacher. The mature student and the working mother, enter the teaching profession in not small numbers, with an enormous wealth of experience to bring added value to the classroom. Then there are the graduate scientists, who generally speaking are of high quality, in their specialist scientific experience but whose University training may have placed them at a disadvantage from the point of view of teaching across the breadth of Integrated Science. Furthermore, their experience has seldom and regretfully placed much emphasis on the applications and implications of science. This has come about through undergraduate courses which in the European tradition have often stressed the theoretical aspects of science and paid little attention to the role of its social relevance or its applications.

These are major problems for which there is no single solution and I will try in this paper no more than raise points for discussion, sometimes I shall give examples of how we are teaching but I shall not suggest that the solutions are necessarily appropriate or relevant to your own situations. I regard this as an important point as too frequently in reports that we produce following our conferences we fall into the trap of too easily using the word 'must'. Whilst guide lines for action will surely be offered we should be cautious and take care to avoid imposing a definitive direction to the way in which change might take place. Whatever processes we suggest should be looked at in the context of the role we hope the teacher will play. There is need for particular care in these matters for by creating dogmatisms we might easily be led to demand the introduction of a particular approach to the teaching of integrated science (or any other change) and thereby impose a condition which could result in a loss of flexibility in the curriculum—and that is too much to lose.

I suspect there is little danger of over-emphasising content and knowledge in integrated science compared with the approach necessary to ensure understanding in our children. Likewise in designing our teacher training programmes, I suspect we all feel that the approach matters at least as much, if not more, than the actual content.

When we hear 'training teachers to teach the Nuffield or any other programme', that seems to me to demonstrate that we are in some way failing. What I hope we are really saying is, that approaches to teaching exist which have been shown in particular situations to be effective. In encouraging these approaches the curriculum materials of a project will of course provide a most valuable and necessary resource.

However, there is also the danger of expecting far, far too much from an initial teacher training programme. To look at pre-service education separately from the continuing education of the teacher is becoming increasingly meaningless.

To me any in-service programme that we may discuss is not only related to the needs of teachers of considerable experience, but also to those in that transition year or the probationary year, following initial training, a year that can be so crucial in the initial professional development of the teacher.

However, the task of this session is to consider the initial training and education of the teacher in the context of the theme of this conference – 'Integrated Science'. May I suggest that only too often this phrase leads to a confusion in interpretation. There is a distinct and important difference between the teaching of integrated science and the teaching that leads to science integrated within the curriculum. It is this latter aspect that applies I believe to a very, very large fraction of the teaching which we have under discussion today. Without doubt it includes the teaching processes most appropriate to the early years of the child in school (and indeed many would say to much of the later stages as well).

There is quite a clear distinction between, on the one hand, the discipline-orientated teaching of a subject, which can be called 'integrated science', and, on the other, the way in which science can be integrated within or arise from the total curriculum. Of course, in practice it is likely that the teacher will not approach his task in such clearly separated ways, and in many of the best situations one often finds some combination of the two. I hope that Herbert Thier would agree that his SCIS group in California have, more than many, come towards that aim. Project Science 5–13 employs the same approach to a greater degree than the largely unstructured basis of Nuffield Junior Science. Nevertheless, there would be I think fairly substantial agreement by each of these projects that whilst the natural development of learning through the child's immediate environment brings interesting opportunities for the development of science, so too, is there always a place for the formalised piece of teaching.

This is the challenge that faces teacher education. What experiences should the student be offered if he is to learn to harmonize these methods and to develop the confidence to capitalise a potentially valuable learning experience. This gift is not one we should wish to restrict to those with the ability to teach science. It is part and parcel of all those qualities that go to make up the effective teacher in the primary school, and ultimately leads to the acceptance by the teacher of responsibility. Although systems may vary and school boards or Ministries or external examinations exert varying degrees of influence, my personal view is that whatever the system, teachers should be educated on the basis that in the long run they should move towards having responsibility for the design for their own curricula. That is, it is they who should be responsible for determining the planned experiences that go on in the classroom.

In considering Integrated Science it is difficult to avoid those considerations of a more general educational character but I will try not to deviate too far from our theme. Speakers yesterday were quite right when they attempted to identify what attitudes and skills and dispositions and knowledges are important to the development of children. Unless we can determine these it is very difficult for us to know how to arrange our teacher training programme in any form of science. This must be the first task in our planning.

We all accept that more than training to ensure the adequate transmission of a body of knowledge is required. It includes the development of attitudes, skills, values, and the handling of controversial issues so often in the past thought not to affect or not to fall within the preserve of the teacher of science. The movement is clear to see and by and large, a tendency can be recognised, particularly in recent programmes of Integrated Science, for an increasing emphasis to be placed on attitude development as opposed to knowledge alone.

The trend involves educating to deal with value situations and controversial issues, and to help by illustrating the ways in which they might arise spontaneously or deliberately in our science teaching. Now of course this can bring enormous problems, the solutions to which need care and sensitivity if the potential teacher is not to be seen by children as too neutral or hypocritical – or dogmatic. The task is not easy and does not always transfer readily between cultures. Our students come to us (and I suspect they are not too different from most others) with very, very little experience of handling situations of this kind.

The balance is delicate between knowing how to preserve culture, saga and folk lore and yet to be able to de-bunk those unscientific practices which so frequently inhibit social progress. Our recent Commonwealth meeting in Jamaica brought to the fore a wide variety of such situations, and the teacher of science needs to learn how to handle them gently. In this he must tread the path most warily and can only too easily find himself rudely at odds with the family which in education should be one of his greatest supports.

Now this is not a thing to which I can pretend to offer an answer, but that is not the prime purpose of this paper. As I have said already the task is to raise the problems, suggest in some instances what is sometimes done but more usually to leave it to each to decide the solution in the light of his own circumstance. Suffice it to say that the role of the teacher with regard to the family and indeed society more generally, is something which perhaps in their preparation may need greater emphasis than is currently offered.

In my own institution a deliberate attempt is being made in a programme where for one whole year out of their training the student gets out of the atmosphere and actually relates himself to social settings which we hope might bring education into context. They are able to spend the time in a variety of ways working either with a social service, with children who are handicapped or deprived or working in an industrial situation. We think it rather important that our teachers in training on this course go a little beyond the cycle of school-university and back to school again. The experiences they are being offered will we hope develop those attitudes which may bring a closer relationship between the scoial and natural sciences particularly in encouraging an appreciation of the applications and implications of science. It would be rash for us to generalise too far in suggesting solutions although I think there is an increasing view that the traditional attempt to understand these problems by philosophical analysis in basic courses is not likely to be very successful. This is just one more example of the wide range of opportunities that face each of us in the education of the integrated science teacher.

Now of course integrated science is just as concerned as other areas with the rational planning of the curriculum. In the past, I think it would be true to say that the traditional approach has been one in which objectives were little more than a commitment to teaching a well-established body of knowledge, orthodox attitudes and the mastery of a number of skills. It would be too easy to undervalue these qualities but the movement towards more child-centred methods, which bring with them greater informality and open discussion of problem situations, has important relevance to integrated science as currently viewed. It would certainly not be original to emphasise the care that is needed if there is not to be confusion between objectives and the methods of achieving them. Although we may be right in thinking we have progressed beyond the point at which they were so often related simply to content, what is to be taught cannot be ignored by the teacher in front of his class. This has in part been the conflict of opinion which has developed between curriculum developers particularly in the primary field. There are those who prefer a completely unstructured approach, where the child is permitted to develop its own interests at its own rate. They feel that by imposing a structure based on content it is likely not only that the child will lose interest but that one is ignoring the differences that occur in individual development. Others prefer an approach structured to varying degrees – but it still leaves us with finding a solution to a prime question. Is the content of an integrated programme appropriate for all children, for all ability ranges – and at what point in their intellectual development? The solution is a task which faces our teacher trainers – but it is more. How does one take a student whose own personal learning experiences may be so alien to what we are now suggesting is desirable? How does one give experiences to the potential teacher whose own education has been highly formalised and who knows no other way? It may be that the process cannot be forced and cannot be too rapid. Once started, however, there is ever increasing impetus to change and I think in the U.K. we are now well over the crest, perhaps because very few indeed of our students have not themselves been brought up and educated in an era of informality in the primary school. It would not be true to suggest that formality does not still exist, but it is a much more relaxed situation than the classroom of 20 years ago. Indeed, I wonder whether this relaxation has come about because of a deliberate emphasis in this direction through teacher education or whether it has in fact been influenced more by changes in society itself and the relationships within the family. Perhaps it isn't until these relationships develop into greater participation between parents and children that it is possible for an informal approach actually to develop in a school situation. The teacher who plays an authoritarian role in the home is likely to do likewise in the school – and finds difficulty in admitting 'I don't know – but let's find out'.

It would certainly be of value if your study groups could discuss whether in your differing social situations such factors are of consequence and how far it is possible to activate such attitudinal change through any training programme.

However, do not let us underestimate a most important aspect of the integrated science teacher – that the teacher understands and has knowledge of science so that he can relate its component parts and achieve a meaningful integration. If we fail to do this, we can be sure that confidence will be missing from the start. To this there is no single and unique solution. In England we have to admit that the background of the intending primary teacher is often particularly weak in science. No training programme can entirely make up for, or ignore the previous educational experiences or short-comings of the student. If there is little confidence in handling a starting point for a scientific activity with children there is little chance that any sensible start will be made. Nevertheless, if only the students can develop a preparedness to learn by discovering together with the child they will acquire many of the experiences which they may have been denied in their own early education. It is therefore good sense that they start out on this road with similar experiences in the course of their training. Fears need to be overcome in students, many of whom are terrified of the word science let alone the activity that is represents. And yet these very same students may already be using the approach in a whole range of their classroom activities (particularly in the creative arts) without recognising the opportunity to draw out the science. It is only a short step actually to bring out these concepts in science from that which is already in their confidence.

As I mentioned earlier factors exist which make the task of the teacher both difficult and certainly different from child-to-child. The varied rate of development and the relative difficulty of ideas is something with which we are all familiar. Much has been said and written on this theme but it does not detract from the importance we should give in our training to an adequate introduction to child development and in this, sociological as well as psychological factors play their part in the encouragement and the development of scientific concepts. If we are to succeed in our objectives for Integrated Science we must find ways of bringing them into consideration by our potential teachers. The task is complex and in many ways terrifyingly difficult to achieve in any limited training period – but a start needs to be made. Whilst many basic principles are common to all societies we know too little of the part played by cultural differences in the stages of development we identify in children. I am no expert in this field (although it is of major importance in any process of curriculum design) but I have recently heard of some extremely interesting work undertaken in West Africa. For instance, I understand that some of the findings related to the ability of children to develop concepts of quantity appear to contradict some of the ideas which we may have of children in a Western Society – just one more example of the care we should exercise in not generalising too far across cultures. Although the formal course in psychology has its part to play in placing various principles into context and perspective, there is a need for support of these studies by first hand experiences. The variety of these is considerable and can be as varied as engineered case studies involving micro-teaching or more direct techniques in the classroom.

I have said little or nothing of the part that can be played by science in the more general formation of the child and yet this should play an important part in the training of the teacher. Science, for instance, has an important part to play in communication. The interaction and dialogue in question and answer, the sympathetic listening, the gradual development of more precise description as the child discovers it needs to record increasingly sophisticated experiences. These are not the preserve of science but it is able to contribute just as much as the creative arts and literature and mathematics are able in their turn to contribute to science.

What I am trying to say is that science at this level is not to me solely a subject on a timetable. It is the way of working with children by which science can be drawn from a variety of activities and equally this science can be used to enhance communication – be it spoken, written or in mathematical form.

The training years are full years in which there is so much to be done. We will have succeeded almost beyond expectation if we can start the teacher so that these scientific activities are introduced with confidence. It requires attitudes of flexibility, frequent questioning and preparedness to be put in a position of saying 'I'm not sure – but let's find out'. This is unlikely to happen if the course of training largely follows a curriculum neatly parcelled into separate studies with little interaction between the different basic educational sciences and tutored in 'non-interactive' lecture situations. This would be the antithesis of what we are attempting to encourage in Integrated Science but it is possible to use other methods which bring alive to the student the important changes in method for which we hope. So too is the need to give experience of the all-important ways in which the classroom can be organised so that the interaction can occur which permits this open-ended approach to science by young children. The part that is played in this by the practising teacher is crucial. It is they with their wealth of experience who are perhaps best suited to guide the student in techniques for the organisation of successful learning – and if they are not, it is important that they themselves be given experience and training in in-service programmes.

So far I have confined myself entirely to the experiences which need to be offered to the non-specialist teacher of science to the young. It presents I believe by far the more difficult problem but I would now like to spend a few moments talking of the factors facing us in the training of the specialist teacher for the upper age ranges in schools. Once more one should stress how limited can be the achievements in courses of initial training which for specialist graduates are often of such short duration. We really should not ask too much but hope that one begins to develop in biologists and physical scientists the attitudes which will lead to a preparedness to seek integration, whilst at the same time giving experiences of the integration of scientific content. Our own limited experience has been most encouraging. The Nuffield Secondary Science and the Schools Council Integrated Science programmes give feasts of opportunity for examples of integration and by case studies we have been able to do much to help the specialist scientist to broaden his range of experience. In our Colleges of Education where longer courses of initial training are more general, some have attempted to do this by offering complementary studies so that no student following a specialist science discipline can leave without having had some experience of working in the broader field. However, few of us who take graduates direct into teacher training have an opportunity to offer such courses – if only because of the limited time at our disposal. This alone has challenged us to use another approach. We have deliberately chosen to put students together in groups from various disciplines so that they learn primarily from each other. We do not attempt to teach them the aspect of science which they may be lacking but rely on knowledge and interest developing by working together with their colleagues on integrated projects. It is early days but there appears to be an encouraging response with skills, attitudes and knowledge developing well beyond their own initial interest. We have also tried to ensure that we don't ignore the part to be played in this by the social sciences. If there is to be a development of science to the fullest extent in the curriculum some regard and realisation must be given to the applications and implications of science. In this, it is our experience that considerable benefits are brought to training by closely associating social science tutors with us directly in laboratory situations.

Lastly, may I just briefly comment once more, that enormous as the task may be and determined as we may be to succeed, our efforts could so easily be frustrated by inappropriate assessment procedures. In some ways this may be sad that they exert such influence, and yet one should perhaps look more on the bright side for this factor alone should be most potent in encouraging and ensuring a change in the directions we seek.

I have tried to suggest some of the experiences which we have thought are desirable to offer to a potential teacher of integrated science. Many of these are common to and needed by those in other areas of the curriculum but I should like to conclude by emphasising two points. Firstly the actual ways that you may find to implement experiences will depend on your systems, institutions, curricula and educators, but secondly and more important initial training can never be more than a start to a life of continuing learning and re-education.

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THE IN-SERVICE EDUCATION OF TEACHERS OF INTEGRATED SCIENCE

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I found the topic of this paper particularly difficult for two reasons. First, philosophically, I do not agree that we can categorize teacher education into pre-service and in-service, as if to assume that these are separate and discreet. Second, the very topic, 'integrated science' assumes that we are going to continue to compartmentalize school curricula into subject content areas, and educate our teachers accordingly. I believe there are other models. The content subject-centred model is a model of western developed countries that has evolved historically. It is not necessarily the best model for underdeveloped, or developing countries. There are ways to organize teacher education other than into strict subject content categories and compartments. We may, for example, instead of preparing physics teachers or science teachers, or English teachers, turn out people who are described as curriculum specialists, or people who can generate small group discussions, or people who are resources specialists. Or people who can generate creative activities, or are versed in cognitive development. It is difficult to find appropriate terms because we have barely begun to explore some of these possibilities.

A fundamental problem for any teacher education program is first to keep up with the pressing changes in society, and particularly, with the changes that have occurred in schools. There has been more change in the ecology of schools and classrooms in the past ten years than in 50 years before that. Too many of our teacher education institutions are educating teachers for the schools that existed thirty years ago. There have been so many changes in clientele, in expectation for the school, that we are lagging behind in our preparation to meet the needs of today's schools. And the further we lag behind, the greater becomes the in-service problem.

I want now to attempt to set the scene for in-service education by taking items that have come from my own experience.

Item 1. I met a former chemistry student whom I used to teach. She was in her third year of teaching and we were discussing how she was enjoying it. I asked her about proposals for extending her education. Her reply was that she had a science degree and appropriate education qualifications, so what more did she need?

Item 2. Another young teacher during her discussions with me said. 'I tried to adopt the discovery approach in my teaching. I know the noise level rises, but when the headmaster comes into my room, I could almost die. You see, he thinks children can only learn when they are seated in rows'.

Item 3. Another said: 'We've got one of those bright young headmasters in our school who wants us to change what we've been doing and develop a unified general studies approach. I don't know where to start, and I don't think he does, either'.

Item 4. A teacher questioned me on innovation with 'What do you think about all this innovation?' 'You know, integrated science is all very well, but they need to have the basics of the separate sciences first. You really do have to have a grounding in physics and chemistry before going on to integrating the sciences'.

Item 5. A teacher to me: 'We've taken on this new primary science course, but we don't seem to have much equipment. It's all very well to talk about string and tin cans and local things, but where do I get time to handle it all?'

Item 6. Teacher: 'I've heard that Bill Smith, over at Montclair High School, is working along a similar line to me with his junior secondary students. Yet we can never seem to get together to discuss it. And I'd like to know more of what he's doing'.

Item 7. Teacher: 'I really would like to take on an integrated science program. But you know, my background is in physics. I enjoy physics, even though I realize some of my students do not. I just would not know where to begin'.

Item 8. Teacher: 'It's all very well for these curriculum experts in the ministry of education to propose a new syllabus. They don't have to teach it. You ought to see my class. If you knew the background of some of them, why a quarter of them are functionally illiterate, as many have one parent, and none of them are interested in school. And by the time I've got them quiet, half the lesson is over'.

Item 9. Senior Teacher: 'We get these student teachers from your college out here. I don't know what you fellows are doing in the college, but they don't seem to know much about science, and they cannot teach very well, either'.

Item 10. Teacher: 'You know, I have some good activity work going on in my science class; this integrated program is good. But all my efforts seem to be killed because other teachers are still teaching in the traditional way in my school'.

The whole of teacher education begins with money, the only tangible resource we have in education now. If your budget is like mine, as much as 80% of it goes into salaries. And when you pay someone a salary all you are paying for is his time. We should analyze much more closely than we do what teacher educators do with their time.

In our attempts to improve science teaching in schools we have tended to develop curriculum materials in big projects largely separate from the schools and the teacher education institutions. The development of curriculum materials has not been closely tied to the education of teachers. From our pre-service education programmes there has been an expectation that the institution produces a complete teacher, fully versed in all he needs to know. Yet when this teacher reaches the school, we suddenly find we need to offer him much more help. The school he enters does not seem to be the school he was being trained for during his pre-service education. He joins a cohort of teachers already in the schools who need in-service education. Where the need for in-service education is recognized it is generally added on in an ad hoc way, instead of being co-ordinated with a pre-service program and the development of appropriate materials.

Too often there is a lack of co-ordination among pre-service education, the development and the evaluation of materials, and in-service programs to produce an effective teacher of integrated science. It is time we expended as much effort on developing programs to fit the needs of the practising teacher as we do in analyzing and prescribing courses for student teachers in pre-service education.

There are five main interlocking tasks; the development of materials, evaluation of present practices, provision of resources for the teacher, development of evaluation instruments and the education of teachers. Generally we spend money on the development of curriculum materials and on pre-service education, but the other tasks are simply added on. Yet the most important variable in any classroom instruction is the teacher, and we must increasingly direct our attention to the integrated science teacher in his classroom and in his school.

One of the difficulties in the design of in-service education programs is the way teachers should be grouped. Table 1 indicates some of the groups of teachers who may form part of an in-service program, with some of their strengths and weaknesses identified. It is important whenever a program of in-service work is designed, for the target population to be identified and the likely characteristics this population may have. These characteristics may be obtained by test, by discussion or other means.

Table 1 **A PEOPLE GROUPING**

	Knowledge of traditional science content and curricula	Knowledge of recent content and curricula	Skill in teaching traditional content	Skill in teaching unified content	Ability to teach science as an environmental study
The recently trained science teacher.	—	+	—	—	○
The older trained science teacher.	+	—	+	—	—
The teacher, trained in another field teaching science.	○	—	+	—	—
The science teacher with extensive graduate experience.	+	+	—	+	+

The target population identified in the table may be grouped in various ways. They may be grouped so that we put together all of the recently-trained teachers to give a group of people with very similar characteristics. Or, if all of the teachers trained in another field now teaching science, are put together they have very similar characteristics and while this may make the updating of content by a lecture method more effective, it is also very easy for them to group together and reinforce each others' prejudices about science and science teaching. I believe such groupings of similar people can generate a negative situation, in which ignorance is pooled and too much responsibility is put upon the organizers of the in-service program. I believe it is more effective to group people with different characteristics and backgrounds so that there is a much greater knowledge pool in the group.

Grouping people and extracting them from their school teaching situation may not be the best way to develop an in-service program. A much more productive way of grouping people is according to tasks they identify as being relevant to their needs in their own schools. One of the priority tasks at present for in-service education is to prepare teachers by helping them to move along a continuum which may be identified by separate sciences (physics, chemistry and so on), integrated science (themes), unified science (problems, processes), and general studies.

Some other in-service tasks for teachers educators helping science teachers cope with the problems of teaching integrated science arise from:

1 – Integrated science in a large urban school.
2 – Integrated science in a small country school.
3 – Integrated science where the level of literacy of the students is low.
4 – Integrated science where facilities are poor.
5 – Integrated science based on a topic approach.
6 – Integrated science from an eclectric appraisal of curricula.
7 – Integrated science and its relationship to community agencies.

It is very important to realise in the development of in-service programs that we must be thinking of educating teachers for transition. All of our schools and all of our societies are in a state of transition, and they will always be so. Those who have read Toffler's book, *Future Shock* [1] will see dramatized this idea of transition and accommodation for future change. Toffler in his book says that education must shift into the future tense. For too long, education, I believe, has been operating in the past tense. Some of the major tasks that could be part of an in-service program for science teachers include:

1. *Helping teachers learn of instructional materials and media that are available so that they may better design their own instructional procedures.*

   Activities under this heading include:

   - helping teachers work through new materials that are available;
   - allowing teachers to visit and preferably work with teachers already using the materials with students;
   - helping teachers try small extracts from the materials with their own students;
   - providing opportunities for teachers to discuss their experiences with other teachers and especially teachers more experienced in the use of these materials.

The broadening of teachers' horizons is a particularly important part of in-service education. Teachers often prefer, for example, to teach single subject science because they have not had the opportunity to see other alternatives in operation or to examine the curricular needs of students in their schools. Similarly, the fact that they are working in a well equipped laboratory may prevent them seeking opportunities to have their students explore science in the natural environment outside the classroom.

2. *Helping teachers design instructional procedures that best suit the students in their school.*

Teachers cannot do this effectively without being given opportunity to discuss and write down objectives for their science teaching, and then to see other teachers with similar objectives attempting to achieve them. Many simple activities may be generated to help teachers check their present science content or their instructional techniques, and so determine how these relate to the objectives.

3. *Helping teachers understand the nature of their students, their interests, abilities and the way they develop concepts.*

Teachers have a remarkably high cognitive expectation of their pupils. Teachers should have their prejudices exposed to them, and be led to see the implications of theories of child development on instruction. They should also be able to identify which materials seem to have made appropriate allowances for individual differences.

4. *Helping teachers understand themselves and the way they influence the learning of others.*

A teacher should be aware of the attitudes he has to science, his pupils, and to other teachers. In-service programs should have as part of their aims attitudinal change in teachers. This may be done using critical incidents, either on tape or film, discussing methods and so on.

5. *Helping teachers to improve their techniques for the evaluation of the outcome of their science teaching.*

Outcomes to be evaluated include total class progress as a social unit, individual student progress, and progress of the teacher in developing his own skills and competencies.

6. *Helping teachers to understand that science is but part of the total school curriculum.*

This seems particularly difficult to achieve, and will require in-service programs that transcend broad subject boundaries. In the same way unified science is more than the integration of separate subject strands, so the unification and development of a total curriculum for a particular group of students is much more than integrating existing subject curricula.

Some of the materials that are available to teachers to help with some of these target tasks are the Science Teacher Education Project (STEP) materials from the United Kingdom. In Australia we are beginning to adapt them as the Australian Science Teacher Education Project (ASTEP), materials. They are self-instructional materials to help teachers both pre-service and in-service understand the instructional process in science.

We must, in all instances of in-service education where teachers are involved in working on tasks, help them to make their own decisions, not make decisions for teachers. There must be continuing feedback to the pre-service institution about its limitations based on the understandings gained from the in-service experience. Too often in school, and in education, the teacher is an isolated professional, answerable only to himself. We must encourage teachers to become part of a team, and the team must include persons from the formal pre-service teacher education institutions. Teachers more than most professional groups are prisoners of their own experiences and often teach as they were taught. They will only move outside their own narrow modes of instruction if they experience stimuli from others who may relate to children in other ways. If mechanisms can be established so that teachers explore actively with others their instructional problems, then much more responsibility for decision-making about curricula may be left with them. To ensure that teachers are adequately equipped to meet this professional demand, a major in-service program needs to be mounted to focus on the tasks that have been identified.

One area should be highlighted. Teacher self-assessment is very important yet much neglected. The National Science Teachers Association has developed a self-assessment inventory which teachers may use for their own assessment of their professional growth. We need more such instruments to help the teacher of integrated science to understand his strengths and his limitations.

There are a number of issues which must be discussed if a more effective in-service education program is to be arranged.

1. *The pre-service – in-service transition*

Too many pre-service programs leave the teacher with the expectation that he has 'finished' his training instead of the reality that it has only just begun. Rarely is the newly trained teacher followed up by the pre-service institution in his new teaching post. This is an important high priority area of in-service education. Also, too many in-service programs continue to use pre-service techniques on teachers who require quite different methods to broaden their knowledge and expertise.

2. *Science teachers and their relationship to other teachers in the school.*

In some ways, a teacher who has had an extensive in-service program, particularly if he does this by leaving his institution for a period of time may be considered somewhat akin to an organ transplant in a human body. The individual may be accepted for the mutual benefit of the whole school, rejected because his ideas are way out, or, after the first flurry of enthusiasm is dampened, he returns to being what he was before the in-service experience. In-service programs should be designed to meet school needs that are apparent to others in the school and the school should prepare for the changes that the outcome of a program are likely to bring.

3. *The teacher as a teacher and the teacher as a learner.*

For an in-service program to be a success, it is necessary for the teacher to identify when his role is that of learner, and when his role is that of teacher. This ability to change roles is particularly important in teaching integrated science, where no one individual can be expected to, or expect to, know everything. Such role changes become particularly important when heterogeneous groups of teachers, for example, within a school are involved in an in-service program.

4. *Where should in-service occur?*

A major dilemma facing educators preparing in-service programs is the decision concerning where the in-service program is to be held. The choices generally available include:

- a single school servicing the members of the school;
- a single school servicing neighbouring schools;
- a special teaching or in-service centre;
- a university, college, or other community venue.

Each has its role to play, depending on the particular objectives for the in-service program. In general, too much emphasis has been placed on holding in-service activities away from rather than within schools. If increasing emphasis is to be placed on having in-service activities undertaken in schools, whenever the teachers see the need for them, then much more attention will need to be paid to the preparation of kits of material which teachers can work through for themselves, and which provide springboards for teachers to develop their own in-service programs for other teachers in their own schools.

5. *Who should have priority attention in in-service programs?*

How should a school decide a priority system for arranging in-service experiences for its staff? Too often such decisions have been taken arbitrarily, with the keen teachers prepared to initiate their own programs receiving priority treatment. A school should draw up priorities for its in-service effort, and the release of its teachers, taking due regard of its weaknesses, the directions it wants to change, and the kind of curriculum program the school needs to develop.

It is my belief that we need to explore different models which effectively link together the pre-service and in-service education of teachers. The dichotomy pre-service – in-service seems no longer meaningful when continuing education for teachers is becoming increasingly accepted. The model I am going to discuss identifies various phases in the development of a teacher and gives a broad framework by means of which specific activities necessary for the development of a teacher of integrated science may be described.

Four phases in the preparation of a teacher are proposed. The first phase, *a pre-service phase,* which should take three or four years, or at least until the student teacher has gained some minimal level of competence. The pre-service teacher would spend much of this time in a teacher education institution gaining sufficient experience with science taught in an integrated way and experience with teaching gained from frequent excursions out to schools and to other social agencies, exploring ways of helping others learn science.

The second phase is an *intern phase,* which should occupy about a full year after the first three or four years of training, or until such time as the intern teacher has reached a required level of teacher competence. Most of the student's time in this phase would be spent in school, but with frequent excursions back to his College. The intern teacher would feel part of a small team in his school with his College adviser becoming an important part of the team. He should not during this year have full responsibility for a class, but should gradually extend his competence. The interns, the headmaster of the school and the team should feed information back to the College so that the pre-service program may be improved.

The third phase may be described as *field service.* Here the teacher embarks on a full load of teaching, but preferably is still part of a team. Such teams could either be formed within a school or with members of adjoining schools, or both. He receives help in an in-service sense within the school, or from nearby schools, with any difficulties he may have. He begins to develop his own ideas, to try them out, and to feed them back to other teachers in his own or nearby schools and to his College advisers for the general improvement of the education program of other teachers. In this phase the teacher should start to develop ideas about a speciality he may wish to pursue. He should plan his own future development in terms of the needs of his school.

The fourth phase may be described as *in-service.* In this phase, the teacher begins a postgraduate program of study. It should probably begin after about three years of field experience. He would develop his interest, with some study leave time for full time study at a College. In this phase he would be expected to help with the education of new student teachers as well as to work on his own graduate program. One full year in seven or its equivalent may be a reasonable time.

Each of these phases may be conveniently divided into four stages. In the first stage, *introduction,* the teacher is introduced to the total program before him in a particular phase, the expectations held for him by his colleagues, by his advisers, and by the schools in which he is to work. He should at this stage map out a plan for his development as a science teacher over the phase he has entered. For example, in the introduction to in-service, the teacher ought to identify the specific area he is to work on in terms of the needs of his school, discuss this with others in his school and his advisers at the College. The second stage is a *familiarization* stage. Here the teacher becomes increasingly familiar with the major tasks of the phase, and begins the program outlined for him. If, for example, he is to develop learning materials, then he should examine existing materials and try some promising ideas with students so that he may be in a better position to develop his own later. The third stage is one of *practice,* where the teacher becomes competent in the tasks identified as being part of that phase. He improves his techniques by practice and by subjecting himself to clearly worked out evaluation procedures and where possible, modifying his techniques in the light of evaluation. He could develop, for example, his own curricular materials which he will try out in his school. The fourth stage in a given phase is *extension.* Here the person has developed his competence and understanding to such an extent that he can participate in the induction of new people either into that phase or another. For example, a field service teacher could be expected to help with the induction into the school of a new intern, or a teacher in the in-service phase could be expected to be involved in helping others develop new curricula or instructional procedures.

The four phases each with its four stages may be represented as matrix which could be completed by filling in details of expected professional experiences for each stage of the program within each phase.

Table 2 A MODEL FOR TEACHER EDUCATION

	Introduction	Familiarization	Practice	Extension
Pre-Service				
Intern				
Field Service				
In-Service				

I have proposed a model for the consideration of teacher educators for integrated science. Others at this conference have put forward other models. Yet the majority of those interested in integrated science teaching are struggling in the real world of schools and teachers and children to improve what they have. Each group has surprises for the other. We need new models. We need people prepared to struggle to implement them and all must be prepared to meet disappointment and failure at times.

IN-SERVICE EDUCATION – POSSIBILITIES FOR THE FUTURE

If a model similar to the one outlined above is to be applied, the rigid distinctions between pre-service and in-service education will disappear. For too long the education of science teachers has been piecemeal and ad-hoc, with one group handing the student teacher over to the next group who receives him without the necessary effective and continuing collaboration.

The aim of this Conference is surely to prepare more effective science teachers and in so doing to improve the quality of science teaching in schools. Yet good teachers will only be produced if there is a concerted effort on all sides to produce them. There will need to be co-operation among teacher education institutions, employers, consultants, inspectors, schools and other groups. In the next decade we ought to explore a model which could make the education of our science teachers first an integrated and then a unified process.

REFERENCE

1. Toffler, Alvin. Future Shock, Bodley Head, 1970.

OPEN UNIVERSITY COURSES IN SCIENCE AND TECHNOLOGY APPLICABLE TO THE EDUCATION OF TEACHERS OF INTEGRATED SCIENCE

M. J. Pentz
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The Open University was founded in May 1969 to provide university and professional education to those with the keenness and ability to continue their education by study in their own time, and particularly to those who could not likewise obtain education at a university. For these reasons Open University students need no 'A' level, 'O' level or any other formal academic qualification for entry. They are usually over twenty-one and the majority are in full-time employment or working at home. In exceptional circumstances we will accept students under twenty-one if reasons, such as physical disability, or domestic or other circumstances make it impossible for them to attend a conventional institution of higher education. We also expect students to study mainly at home in their spare time.

Our name therefore implies that the University is 'open' as to people; it is also 'open' as to places, for students live in every part of the United Kingdom. The University is also 'open' as to methods, though all aspects of our present courses are integrated. The teaching staff of the University communicate with students in the following ways. Correspondence texts, broadcast programme notes, articles and assignments, are sent through the post. There are broadcasts on television and VHF radio. Study centres are arranged in rooms in a local school or college where students, tutors and counsellors can meet, and where programmes and replays are available. Counsellors also use the local study centres to hold discussion groups, and to give advice on general study problems. Course tutors mark the correspondence assignments, comment on the written work, and hold occasional tutorials at the study centres. All Foundation Courses and many Second Level Courses involve compulsory one-week residential summer schools, usually held in the buildings of other universities, though special arrangements may be made for disabled students. The courses themselves are written by the full-time staff at Walton Hall, where the permanent headquarters of the University are housed on a 70-acre site in north Buckinghamshire. There are few restrictions on the choice of courses, and programmes of study are designed to embrace a wide range of subjects and several disciplines. In fact a student can study both arts and science-based subjects if he or she wishes. No course lasts longer than ten months (January–October) and the 'credits' awarded can be accumulated towards a degree over a number of years.*

Opportunities for Teachers of Integrated Science

It is clearly not possible in such a short paper as this to go into the many aspects of training teachers for integrated science teaching.

It is accordingly restricted to the discussion of three questions:

1 – How many teachers are studying Open University courses?

2 – What courses in science and technology are available or planned?

3 – What are the 'integrative' features of Open University science and technology courses?

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*The opening two paragraphs are reproduced, with permission, from the B.A. Degree Handbook 1972, The Open University.

1. How many Teachers are Studying Open University Courses?

The Open University admitted its first 24,000 students in January 1971. Some 16,000 of these students continued their studies in 1972 and a further 20,000 new students were admitted. In January 1973, 17,000 new students were admitted. With 11,000 of the 1971 intake and 13,000 of the 1972 intake continuing, this has brought the undergraduate population up to a total of 41,000. Meanwhile, the first 900 students, all of course from the 1971 intake, have already qualified for their ordinary BA degree. The number of graduates per annum is expected to rise rapidly over the next two or three years and reach a steady figure of 4 – 5,000 by 1976.

Thus the Open University has, in only a very few years since its foundation, already become the largest (in terms of number of undergraduate students) in Britain.

As might be expected, for all three years teachers have constituted the largest single occupational group in the student intake. See Table 1. But their proportion had declined significantly since the first year.

Table 1 TEACHERS IN THE JANUARY INTAKE

1971		1972		1973	
Number	% of total	Number	% of total	Number	% of total
8,960	37	6,170	30	4,900	29

With a 'survival rate' that appears to be marginally higher than that of some other occupational groups, we find that teachers made up 42% of the students continuing in 1972 as compared with 37% of the 1971 intake.

We have estimated that in the three years 1971 – 73 some 5,000 teachers have been admitted to the Science or Technology Foundation Courses, and that in the current academic year (1973) there are about 5,000 teachers studying science or technology courses (including interfaculty courses with a science or technology component).

These figures establish that whatever effects Open University courses in science and technology may have on the ability of British teachers to teach science in an integrated fashion, they are not on a small scale.

2. What courses in Science and Technology are available or planned?

A detailed description of the courses in science and technology already available to Open University students or planned for presentation in the immediate future would take up much more space than is available in this short paper. The undergraduate course programmes of the two faculties are summarized in Table 2. To understand this chart one needs to know a few basic facts about the Open University and about the faculties concerned.

The Open University offers a *BA degree* at two levels, Ordinary and Honours. To obtain a BA, the student must obtain six credits, of which two must be at Foundation Level. To obtain a BA (Honours), the student must obtain eight credits, of which two must be at Foundation Level and two or more must be at Third Level. There are no other restrictions on a student's choice of courses. He may choose courses from any number of faculties. A *credit* involves an

THIRD-LEVEL SCIENCE COURSES		Credits
BIOLOGY	Physiology of cells and organisms	½
	Biochemistry and molecular biology	½
	Ecology	½
	Evolutionary biology	½
CHEMISTRY	Chemistry – an integrated course	1
	Principles of chemical processes	½
	Experimental chemistry	½
EARTH SCIENCES	Internal processes	½
	Earth Sciences, techniques and methods	½
	Oceanography	½
PHYSICS	Solid state physics	½
	Statistical mechanics	½
	(Astrophysics and planetary science	½)
ALL DISCIPLINES		7

SECOND-LEVEL SCIENCE COURSES	Credits
Many combinations of courses in: comparative physiology, biochemistry, genetics, chemistry, geology, geochemistry, geophysics, geobiology (environment), Earth's physical resources, totalling 5 half-credit courses	2½

	Credit
SCIENCE FOUNDATION COURSE	1

THIRD-LEVEL INTERFACULTY COURSES		Credits
SCIENCE/MATHEMATICS	Quantum theory and atomic structure	½
SCIENCE/MATHEMATICS/ TECHNOLOGY	Electromagnetism	½
SOCIAL SCIENCE/ TECHNOLOGY	People and organization	½
ALL THIRD-LEVEL INTERFACULTY		1½

SECOND-LEVEL INTERFACULTY COURSES		Credits
SCIENCE/TECHNOLOGY	Solids, liquids and gases	½
	Optics, images and information	½
	Principles of chemical processes	½
TECHNOLOGY/SCIENCE	Introduction to materials	½
	Electromagnetics and electronics	½
MATHS/SCIENCE/ TECHNOLOGY	Elementary mathematics for science and technology	½
	Mechanics and applied calculus	½
SOCIAL SCIENCE/SCIENCE	Fundamentals of psychology	½
TECHNOLOGY/ SOCIAL SCIENCE	Urban development	½
SCIENCE/SOCIAL SCIENCE/ TECHNOLOGY	Biological bases of behaviour	½
TECHNOLOGY/SCIENCE/ SOCIAL SCIENCE	Technology and human ecology	½
ARTS/SCIENCE/TECHNOLOGY	Science and the rise of technology since 1800	½
ARTS/MATHS/SCIENCE/ TECHNOLOGY	Science and belief (from Copernicus to Darwin)	½
ARTS/SOCIAL SCIENCE/ TECHNOLOGY	Art and the environment	½
TECHNOLOGY/MATHEMATICS	Computers	½
MATHS/SOCIAL SCIENCE/ EDUCATION/TECHNOLOGY	Statistics	½
ALL SECOND-LEVEL INTERFACULTY		8

	Credit
MATHEMATICS FOUNDATION COURSE	1

THIRD-LEVEL TECHNOLOGY COURSES	Credits
Systems modelling	½
Human factors and systems failures	½
Manufacturing systems	½
Electronic design	½
Electronic materials and devices	½
Control	½
Telecommunication systems	½
Materials processing	½
Designing materials	½
Materials under stress	½
Fluid dynamical modelling	½
The built environment	½
Engineering design	½
ALL THIRD-LEVEL TECHNOLOGY	6½

SECOND-LEVEL TECHNOLOGY COURSES	Credits
Engineering mechanics	½
Systems behaviour	½
Instrumentation	½
Man-made futures – design and technology	½
Systems management	½
Designing the future	½
ALL SECOND-LEVEL TECHNOLOGY	3

	Credit
TECHNOLOGY FOUNDATION COURSE	1

Table 2: Chart of Open University Undergraduate Courses in Science and Technology

Reproduced with permission, from the 'Introduction and Guide to the Science Foundation Course', The Open University.

average student in about 360 hours of study spread over an academic year of 42 weeks, plus about 60 hours' work at a one-week residential summer school. He gains a credit on the basis of a combination between continuous assessment and an end-of-year examination. Students with previous higher educational qualifications may be awarded up to two (and in special cases three) *credit exemptions.* Most teachers have qualifications entitling them to two or three such credit exemptions. With the exception of the Foundation Courses and one of the third-level courses, all the science and technology courses have half-credit ratings. This offers the student a wide range of options in making up the degree programme of his choice.

Broadly speaking, in science and technology, a second-level course is one which has a Foundation Course as prerequisite and a third-level course is one which has a second-level course as prerequisite. The Science Faculty is staffed in four discipline areas: biology; chemistry; Earth sciences; and physics. The Technology Faculty is staffed in five discipline areas: design; electronics design and communication; engineering mechanics; materials science; and systems.

Thus the courses offered are mainly in these disciplines or in combinations of them. In addition to the courses produced entirely by the staff of one or other faculty, there are, as Table 2 shows, a number of interfaculty courses. These are produced by staff of two or more faculties. All courses, whether 'single-faculty' or interfaculty, are produced by *Course Teams.* For information about the Course Team approach to course production in the Open University and about the systems approach to course design, the reader is referred to the paper by A. R. Kaye and M. J. Pentz. [1]

It will be apparent that with the array of second and third-level courses shown in the chart, a student has a very wide range of choice of courses, even if he restricts himself to the science/technology area. Many students with an interest in science (particularly physics) or technology are likely to be interested in mathematics. Apart from the Mathematics Foundation Course (included in the chart to emphasize this point) there are several higher-level mathematics courses that would be useful to such students. Large numbers of students studying the Psychology and Biological Bases of Behaviour courses have in fact taken the Social Science Foundation Course, rather than the Science Foundation Course; many have taken both. Smaller, but not insignificant, numbers of students are opting for various Arts/Science or Arts/Technology combinations. There is no doubt that a teacher wishing to equip himself with a broad range of science-based courses so as to enhance his ability to teach integrated science will find that the Open University course programme offers him plenty of scope.

At the other extreme, many students – indeed the majority, on the information we have – are interested in an Honours degree with the maximum possible concentration of a particular discipline. As will be evident from the chart, such a student could choose second and third-level courses so as to obtain between three and four out of eight credits essentially in a single 'discipline', such as biology or chemistry. A number of British Universities offer 'General Honours Degrees' in which the single-discipline content is about half. Thus an Open University student can, if he wishes, obtain a very similar qualification to these.

The chart in Table 2 shows only undergraduate courses. The Open University has a major programme of *Post-experience Courses,* which will include courses specifically designed for science teachers. One such course, 'Technology for Teachers', is already in preparation and a course on science teaching methods intended primarily for teachers of integrated science in secondary schools, is at the planning stage.

3. What are the integrative features of Open University science and technology courses?

It seems self-evident that Open University courses can contribute to the education of teachers

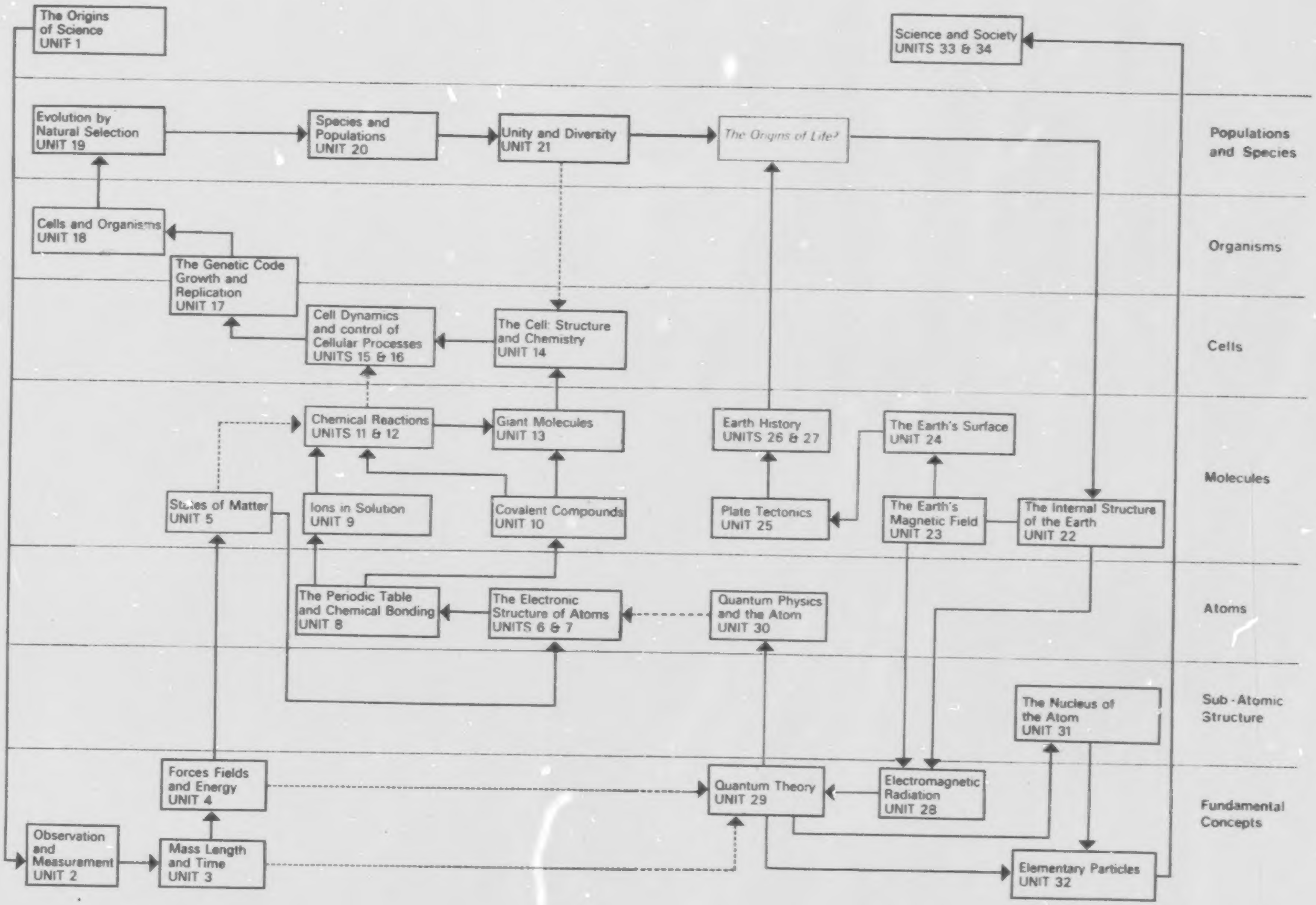
The Origins of Science UNIT 1
Science and Society UNITS 33 & 34
Evolution by Natural Selection UNIT 19
Species and Populations UNIT 20
Unity and Diversity UNIT 21
The Origins of Life?
Populations and Species
Cells and Organisms UNIT 18
The Genetic Code Growth and Replication UNIT 17
Organisms
Cell Dynamics and control of Cellular Processes UNITS 15 & 16
The Cell: Structure and Chemistry UNIT 14
Cells
Chemical Reactions UNITS 11 & 12
Giant Molecules UNIT 13
Earth History UNITS 26 & 27
The Earth's Surface UNIT 24
States of Matter UNIT 5
Ions in Solution UNIT 9
Covalent Compounds UNIT 10
Plate Tectonics UNIT 25
The Earth's Magnetic Field UNIT 23
The Internal Structure of the Earth UNIT 22
Molecules
The Periodic Table and Chemical Bonding UNIT 8
The Electronic Structure of Atoms UNITS 6 & 7
Quantum Physics and the Atom UNIT 30
Atoms
The Nucleus of the Atom UNIT 31
Sub-Atomic Structure
Forces Fields and Energy UNIT 4
Quantum Theory UNIT 29
Electromagnetic Radiation UNIT 28
Fundamental Concepts
Observation and Measurement UNIT 2
Mass Length and Time UNIT 3
Elementary Particles UNIT 32

Table 3: Structure of the Science Foundation Course (Reproduced, with permission, from the Introduction and Guide to the Science Foundation Course) *Prepared by the Science Foundation Course Team*

of integrated science in two ways. One way is to provide the teacher with something to integrate. If he has only learned biology, he can hardly be expected to teach biology and chemistry and physics and Earth science, whether 'integrated' or not. The other way is to offer him courses of study which are themselves 'integrated'. 'Integration' and 'integrated science' mean different things to different people. The concept of 'integration', as it has been applied to Open University science and technology courses, can best be illustrated by taking a closer look at the structure of the Science Foundation Course. See Table 3.

The opening paragraphs of the Introduction and Guide to the Science Foundation Course read as follows:

> "One of our aims in designing this Course was that it should be an integrated multi-disciplinary course, with contributions from physics, chemistry, biology and Earth science, but linked together in such a way as to demonstrate the unity of science as well as its diversity. We try to show what is common to all the disciplines as well as what is special to each. This has seldom been done before at first-year undergraduate level.
>
> Another aim was to teach science in its social context – to bring out clearly the relationship between science and society. Again, this is breaking new ground. A few universities in Britain offer special courses about Science and Society, but none attempt to teach the main science courses themselves in this way".

We sought to achieve these aims by giving the Course an internal structure which would emphasize the inter-relationships and internal unity of science by making as explicit as possible the historical roots and social relations of science. Thus, we begin in the first Unit of the Course by tracing the emergence of science and scientific method in man. We see science as a human activity developing within a particular technological and social context and interacting with it. Science depends on tools which are themselves extensions of man's senses of touch, sight and hearing, and the use of these tools, or instruments, for observation and experiment is the basis of the scientific method.

Our consideration of the nature of scientific method leads us to look into the problems of experimentation, deduction and induction, hypothesis-making and theory. The nature of the 'laboratory' and the limitations of scientific method and technique are also discussed. And in the final two Units of the Course we introduce two case studies which show what can be the social implications of scientific decisions. One is the story of nitrogen fixation and the other is that of nuclear energy. These case studies raise once again the relations between science, technology and society which were discussed, briefly, in Unit 1. We see that the relations between them are crucial to the development of all three; each affects the others. It is in this context that we examine the making of scientific choices at the levels of the individual scientist in the laboratory, the scientific administrator and the politician. It becomes apparent that the scientist has a responsibility to society and that society has a responsibility for science.

In parallel with the whole Course, and intended as a further integration device, is an essay on the Historical Roots of Present-Day Science, specially written for the Course by J. R. Ravetz. This essay 'takes off' from Unit 1 and describes a sort of parabola, bridging the Course and re-joining it in Unit 33. But it is a bridge with supports firmly based on the Course material and there are many references back to the main Course from the essay as well as links out to it from the main Course. Through this essay, we aimed to provide the student with a different sort of history from that given in many conventional science textbooks, in which one often reads of the history of science as if it were the activity of a series of great men, working in isolation from the society which surrounds them, and unaffected by the social and political currents of their time. The intention of this essay is to correct this balance, to show the way in which, throughout its history, the intellectual development of science, the establishment of an ordered vision of the world, rational and interlocking, which forms the main substance of our Foundation Course, has been affected by, and has in its turn affected and changed these social currents.

The primary aim of the Technology Foundation Course is to explain what technology is, how it operates and how it interacts with the life of the community. It too is concerned with the internal logic and the external relations of the subject as the stated aims of course T100 'The Man-made World' make clear:

> "The aim of the course is not only to explain and demonstrate the many aspects of the way engineers, designers and others do their job, but also to assess its impact upon us all.
> Technology is not just applied science or applied mathematics or a collection of inherited skills, though they all play a part. It is creative and imaginative, it has a methodology all its own and it is to do with people. Thus our course is both for those who want to have a hand in shaping society but have never before encountered technology, as well as for those already involved in it and who want to extend their ability and insights. No special prior knowledge of science or mathematics is required".*

Inasmuch as the history, ideology and social relevance of science derive from the threefold interaction between science, technology and society, it seems plausible to suggest that such a course in technology, if it is properly designed, could be of value to the teacher of integrated science.

Many of the second-level science and technology courses that have been produced in the Open University so far have similar characteristics to the Foundation Courses – they are multidisciplinary in content, integrative in approach and relate the subject to the social context.

It may thus be concluded that science and technology courses of the type being taught in the Open University could make a significant contribution to the education of teachers of integrated science. Large numbers of teachers are studying these courses. Whether their studies do in fact affect their abilities to teach integrated science is a matter of research. This research has yet to be undertaken.

REFERENCE

1. **Integrated Multi-Media Systems for Science Education which Achieve a Wide Territorial Coverage,** UNESCO, New Trends Series, Paris 1973.

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*Reproduced, with permission, from 'The Man Made World', The Open University, 1971.

NEW APPROACHES TO THE PREPARATION AND IN-SERVICE TRAINING OF TEACHERS OF INTEGRATED SCIENCE, INCLUDING THE TEACHER AS AN EVALUATOR OF STUDENT LEARNING

Report of Working Group Wa.
Chairman: Peter Fensham, Monash University, Victoria, Australia
Rapporteur: Donald W. Harlow, The Royal Society, London

Integrated science teaching in schools in most countries is in its infancy. As yet, little attention has been paid to the specific aspects of teacher education that are involved when science teaching moves towards a more integrated form. Some programmes of pre-service and in-service preparation have been, or are being, currently tried, but few have yet been used long enough to provide substantial experience. However, these trials have identified a number of problems that must be considered in future approaches to teacher education in this field.

At the primary level the teaching of science almost everywhere has an integrated character, so the preparation of teachers is here synonymous with preparing them to include science in their total programme. Since most primary teachers have very little scientific education themselves (and often have a real sense of failure in its study), this is a severe problem.

At the secondary level, the problems are very different. The sciences have been taught for a long time in non-integrated ways. Most teachers and intending teachers will have studied science themselves in courses with very little integration. Here, it is a case of re-orientating specialists and preparing new teachers for the particular characteristics and objectives that the integration of science teaching implies.

Furthermore, the teaching of the sciences in schools – whether separated or integrated – has been revised radically in many new curricula. This, in itself, has raised new general targets for science teacher preparation programmes. We have therefore directed our attention to those aspects of teacher education that are certainly associated with the teaching of integrated science, although many of them may not be exclusive to it. Where possible, such special features will be mentioned.

Composition of the Working Group and the Nature of its task

The group was a large one with more than 35 countries represented in its more than 60 members. Many of these persons had prepared papers for the meeting, and a great deal of valuable experience is contained within them. They are listed in the Report of the Conference [1]. Although many ideas from these papers are included in this report, they did reveal how much teacher preparation programmes, like other curricula, need to be rooted in the particularities of a local context. Cultures and educational systems provide such a rich variety of antecedents and outcome situations, that it is foolish to imagine that a detailed programme in one place can be transferred without major adaptation to another. However, this does not mean that certain general features are not common to a number of situations in both the developed and developing world. It is because of our interest in these generalities that we discussed and developed a number of models for teacher preparation. Models of teacher education are, like models of anything else, limited representations only of a real programme. We have tried to tease out from the reality situations, with all their local detail, some of the more universal elements that must be considered by teacher educators in many places. All models are limited by their simplistic nature, and some will apply better to teacher education under certain conditions. Some of the strengths and weaknesses of our models are indicated.

Teacher preparation can be considered at a variety of levels of generality. At a very general level, we can consider two models of great interest for the introduction of the new objectives and modes of teaching that are involved in many integrated science programmes. These are shown in Figures 1a and 1b.

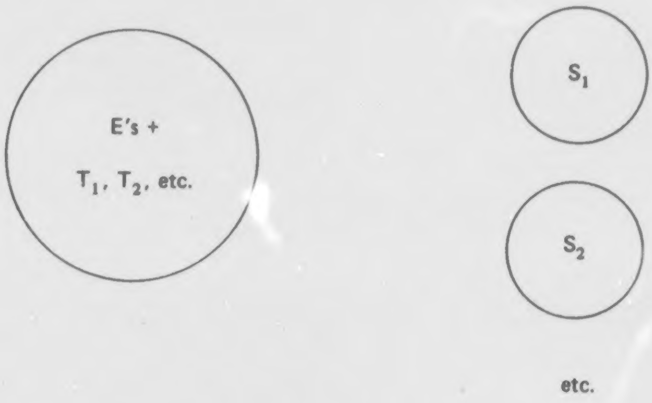


Figure 1(a) 'AWAY FROM SCHOOL' MODEL. 'Experts' (E's) and Teachers (T's) from Schools (S) gather for a programme of training in an institution or centre located away from the schools.

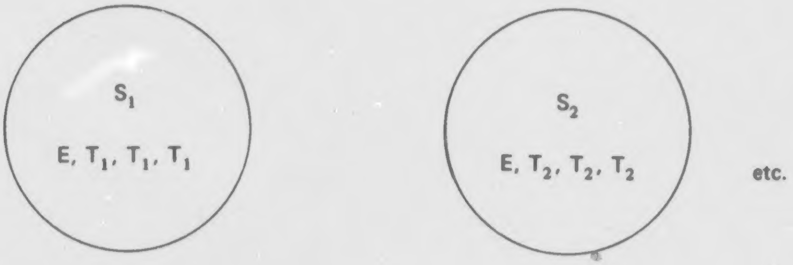


Figure 1(b) 'WITHIN SCHOOL' MODEL. Experts come to schools (S_1, S_2, etc.) and the training takes place within it for its' group of teachers.

The *'AWAY FROM'* model is the usual form of pre-service training and has been the pattern for the great majority of in-service programmes, including some from Ghana and Peru which were reported to the groups. Examples of the *'WITHIN'* model from the West Indies and the U.S.A. were described. The Teacher Centres being extensively tried in England are clearly examples of a model intermediate between these extremes and interesting examples of *AWAY FROM* followed by *WITHIN* were given from New York State and Teacher Centres in the U.K. and an example of the *WITHIN* followed by *AWAY FROM* intermediate model from the West Indies is discussed in more detail later in this report.

A growing body of data and opinion suggests that without at least some component of *WITHIN* character, teacher training programmes of the *AWAY FROM* type have disappointing results. This may be particularly true for integrated science teaching. Its goals and features may be less well understood by the schools to which teachers go, or return, from training, than are other targets of teacher preparation programmes.

More Specific Models

At the more specific levels, models can be constructed and considered that relate to particular aspects of training courses. For example, the problem of broadening the science background of hitherto specialist science teachers has been tackled in a number of different ways. A model that is common to a number of these is the mutual, peer group teaching one shown in Figure 2.

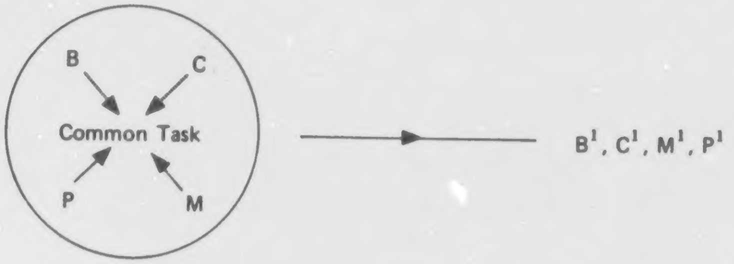


Figure 2 **Teachers with strengths in Biology (B), Chemistry (C), Physics (P), and Mathematics (M) work together on a common task of an integrated type, contributing to it, and to each other, leading to specialists (B^1, C^1, M^1, P^1), somewhat more orientated towards, and confident in integrated work in science.**

This model has been used in the pre-service course at the Centre for Science Education, Chelsea College, England, with the preparation of a field study as the common task. At Rosskilde University in Denmark, a science project is the common task, and in Milwaukie and in the schools working with the Centre for Unified Science Education the innovation of the new curriculum is the task. These are encouraging signs that mutual teaching can be a major contributor to the particularly thorny problems of integrated science teaching. Other papers before the group suggest many other models for different aspects of training programmes for integrated science teaching. A multi-dimensional model was described by de Llopis Rivas as a means of suggesting how science content and pedagogy could be selected and inter-related in a formal course for integrated science teachers. Bojorques used models from systems analysis to identify what type of laboratory experiences could be included in training programmes and how they can be best used to develop integrated science objectives. Connor and Parsegian, both in the U.S.A., were concerned with models to ensure that the move to integration did lead to a humanising outcome from the study of science.

Competencies and Needs of the Integrated Science Teacher

Inevitably a group discussing models or programmes for preparing teachers of integrated science, will need to have in mind some desired outcomes in the teachers they are preparing. One such list was produced in the group and the competencies it contains are now given.

(i) He should have an acquaintance with different materials for the teaching of integrated science, and be able to identify differences and similarities in their aims and philosophy.

(ii) He should be able to suggest and set up suitable experiments from available materials, and be able to guide students to do them.

(iii) He should be able to carry on an inquiry-orientated teaching programme, and be able to participate in class with children in discussions, etc., as a group leader and 'facilitator' to sources of information.

(iv) He should strive for unity in knowledge of all kinds, and convey this attitude to his students.

(v) He should recognise the expertise that others have to offer, welcome their contributions, and hold high standards of performance for himself and his students.

(vi) He should have some minimum knowledge of science and understanding of its role in the lives of the people in the community.

Another sub-group preferred to consider what an integrated science teacher will need to carry out his or her task. Their summary is given in Figure 3.

In our discussions of both needs and competencies, there was a continuing emphasis that any programmes for them must give to teachers an appreciation of the social significance of science for the world in which we all live. What is socially significant will depend largely upon the conditions of local regions.

Teaching Integrated Science in Primary Education

At this level, the teaching of science is unencumbered with vocational aspects or with the selective or preparatory tasks so evident in association with science in secondary schooling. Its place in primary schooling is thus justified only in so far as it is relevant and a contributor to the general development of the knowledge, skills and attitudes of the child. In advanced countries pollution, the consumption of power and other resources, or national health plans, may be some of the significant problems. In others they may be those of community development. In either case, there are questions which involve the applications of scientific knowledge and technology. Teachers must be helped to make their contribution to a more scientifically literate population who can better contribute to the personal and national decisions that are required.

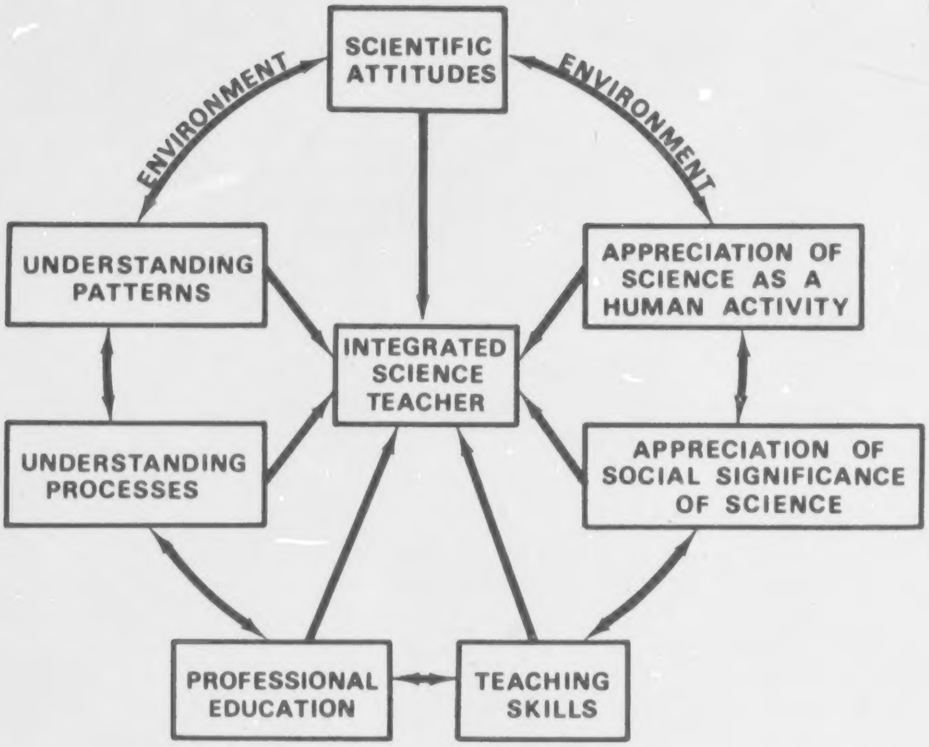

SCIENTIFIC ATTITUDES
ENVIRONMENT
ENVIRONMENT
UNDERSTANDING PATTERNS
APPRECIATION OF SCIENCE AS A HUMAN ACTIVITY
INTEGRATED SCIENCE TEACHER
UNDERSTANDING PROCESSES
APPRECIATION OF SOCIAL SIGNIFICANCE OF SCIENCE
PROFESSIONAL EDUCATION
TEACHING SKILLS

Figure 3. **The basic needs of a teacher of Integrated Science.**

Programmes for the pre- and in-service training of primary teachers for integrated science can be considered using the model framework shown in Figure 4.

Just as the technological characteristics of particular situations can vary immensely, so can the resources and constraints for primary schooling from one country to another or even from region to region within a country. Books, equipment, examinations, teacher freedoms, promotions procedures all contribute to this variety. The strategies or transactions that form the curriculum of the teacher education programme (3) will need to take account of these particularities (1) and (2). Acknowledging these inputs the strategies are aimed at some desired characteristics and skills (4).

The feedback loop (5) relates the strategies and competencies to the realities and possibilities in the actual situation. This could, for example, be the *WITHIN SCHOOL* follow up of an *AWAY FROM SCHOOL* programme mentioned above. It can, in quite another way, hopefully lead to a bootstrap process of overall development of the community.

The following aspects are seen to be of great importance if the programmes related to this model are to succeed.

(a) The curriculum planners and executors of the strategy must themselves be intimately

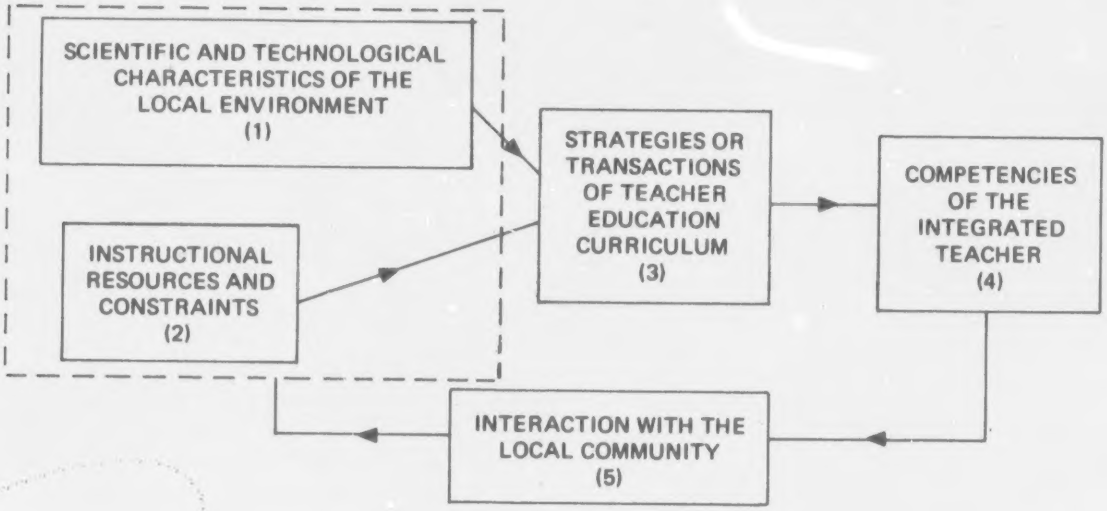

SCIENTIFIC AND TECHNOLOGICAL CHARACTERISTICS OF THE LOCAL ENVIRONMENT
(1)
INSTRUCTIONAL RESOURCES AND CONSTRAINTS
(2)
STRATEGIES OR TRANSACTIONS OF TEACHER EDUCATION CURRICULUM
(3)
COMPETENCIES OF THE INTEGRATED TEACHER
(4)
INTERACTION WITH THE LOCAL COMMUNITY
(5)

Figure 4. **Interactive model for planning teacher education programmes.**

involved in the community in which they are working as teacher educators. Only then will the appropriate stimuli exist for evaluation and feedback to occur.

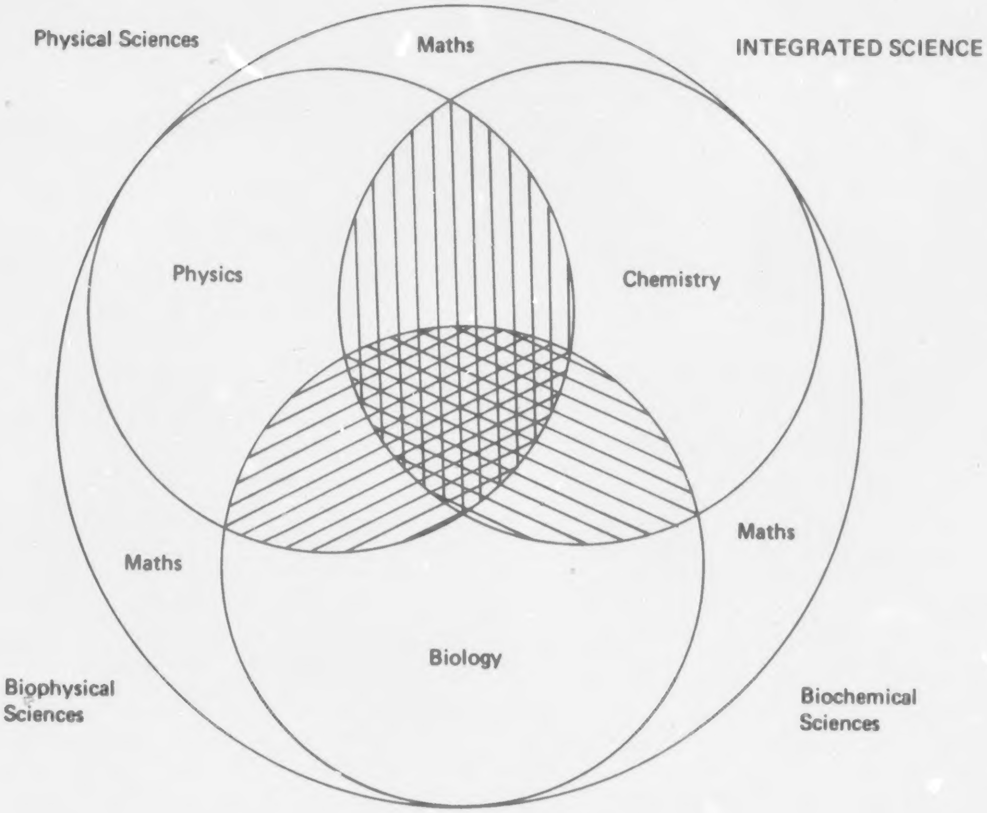
(b) Application of a model is a continuous process of evaluation and adaptation. It is therefore neither possible nor desirable to import detailed programmes from other communities much less from an advanced to a developing country, or from training programmes for a disciplinary approach to an integrated one.

(c) Curriculum for preparation of primary teachers should be problem-orientated. Inquiry, rather than course content, independent as against directed study; foundation sciences always interwoven with classroom and social situations, should form the central themes of any programme.

(d) Strategies for improvement in teaching techniques alone may not be sufficient. Motivation of the teacher can be maintained high provided his curriculum is relevant to needs of society, if teacher feedback is given more serious treatment, and if the teacher-educators maintain continuous direct contact with pupils in schools.

Pre-Service Preparation of Secondary Teachers

Secondary schooling in almost all countries still has science taught as separate disciplines. This occurs for many reasons, some of which relate to the important roles that secondary education play in vocational preparation and in laying a foundation for tertiary studies in the sciences. Accordingly, the teaching of integrated science in secondary schools needs to be considered in relation to the existing teaching of the separate sciences. It can be regarded as a dimension of approach to teaching science rather than an established domain of the whole curriculum and can be expressed with a model like that of Figure 5.


Physical Sciences
Maths
INTEGRATED SCIENCE
Physics
Chemistry
Maths
Maths
Biology
Biophysical Sciences
Biochemical Sciences

NOTE (i) Model is a 'content' view
(ii) Model simplified to show only major areas of science – other content combinations are possible.

Figure 5. **A model to identify the possibilities of integrating or correlating the separate sciences in secondary teaching.**

At the secondary level this approach will be the responsibility of a teacher who is primarily in the school as a teacher of science. Whether or not he had specialist training himself or still taught some disciplinary courses, he would endeavour to present as holistic a view of science as possible. To do this he would need to draw on a wide diversity of contexts which emphasised concepts, themes, and principles that are common to a number of sciences. Once again, these contexts will need to be relevant to the local community of the teacher and students, if the commonality is to be perceived as natural and meaningful. Attempts to show common features in purely scientific contexts often simply become one more level of abstraction.

The model of teacher needs – Figure 3 – was used as the base for considering the more particular aspects that should be covered in pre-service secondary training. An elaborated model resulted and this is shown in Figure 6.

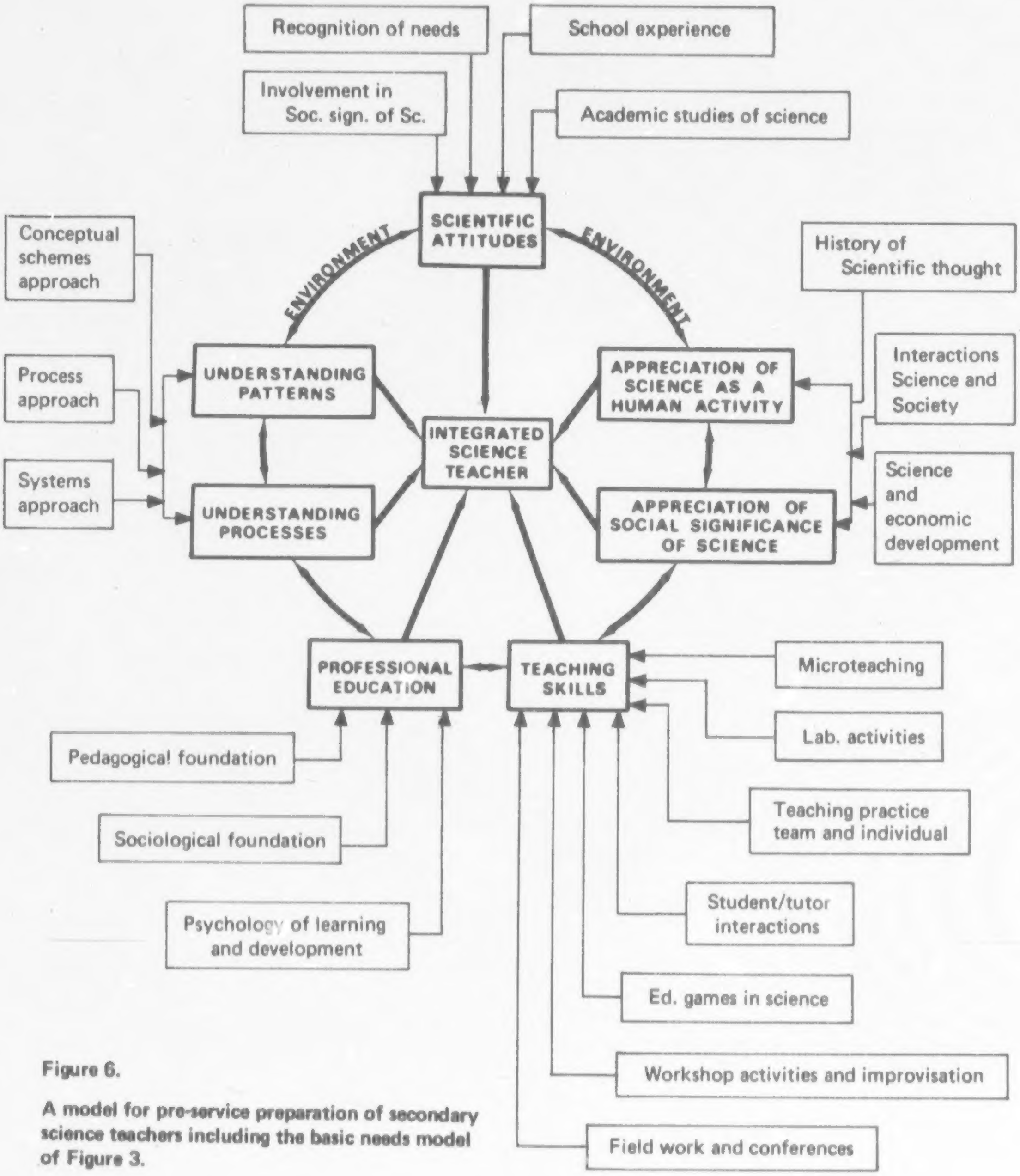

Recognition of needs
School experience
Involvement in Soc. sign. of Sc.
Academic studies of science
SCIENTIFIC ATTITUDES
ENVIRONMENT
ENVIRONMENT
Conceptual schemes approach
History of Scientific thought
Process approach
UNDERSTANDING PATTERNS
APPRECIATION OF SCIENCE AS A HUMAN ACTIVITY
Interactions Science and Society
INTEGRATED SCIENCE TEACHER
Systems approach
UNDERSTANDING PROCESSES
APPRECIATION OF SOCIAL SIGNIFICANCE OF SCIENCE
Science and economic development
PROFESSIONAL EDUCATION
TEACHING SKILLS
Microteaching
Lab. activities
Pedagogical foundation
Teaching practice team and individual
Sociological foundation
Student/tutor interactions
Psychology of learning and development
Ed. games in science
Workshop activities and improvisation
Field work and conferences

Figure 6.

A model for pre-service preparation of secondary science teachers including the basic needs model of Figure 3.

This extended model is intended to be self-explanatory and its components largely speak for themselves. It includes a number of suggestions for the ways the basic needs can be met. These came from the wide range of experience within the group. Not so easy to express in the model were the important elements of a positive attitude and enthusiasm for science and its contributions and limitations in education and in society. It was also felt that the integrated approach required perhaps a greater appreciation of the importance of mathematics as a language for science than do the separate sciences where its use may rather be as a tool.

Perhaps special comment can be made about the left hand boxes in the model. The way in which science teaching can contribute to students' abilities to recognise and use patterns to solve social, domestic and scientific problems lies, we believe, at the heart of the integrated approach to science teaching.

In-Service Training of Secondary Teachers

In-service training is concerned with the science teacher who has already had some pre-service training and some experience as a teacher of science, almost always in a non-integrated fashion. The problems here are compounded because of the usually inadequate time given to such in-service work and the fact that established patterns of teaching are often being challenged. In some cases, in-service work may also be trying to supplement very limited original backgrounds. The variety of the tasks can be considered using the model of Figure 7.

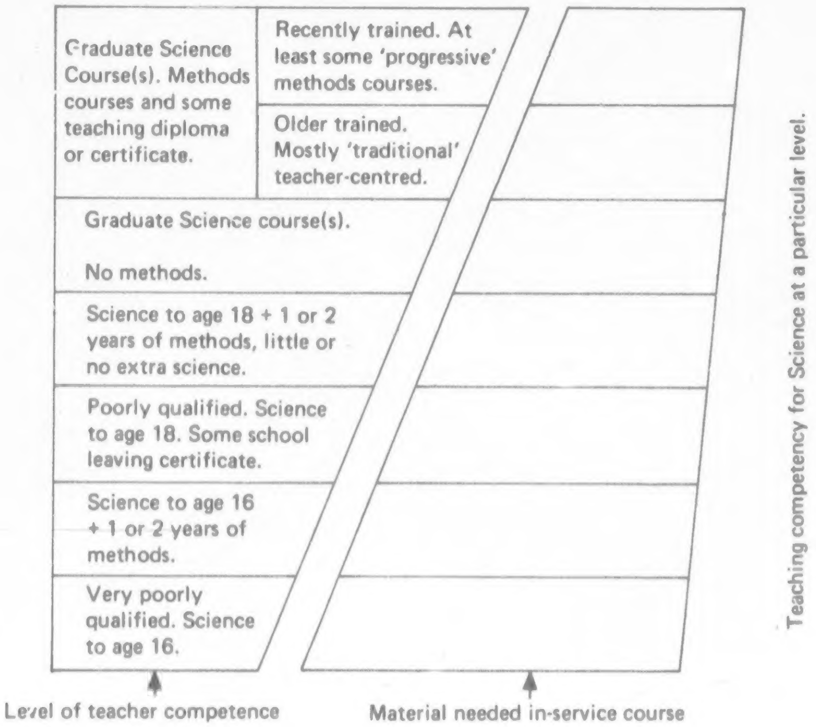

Graduate Science Course(s). Methods courses and some teaching diploma or certificate.
Recently trained. At least some 'progressive' methods courses.
Older trained. Mostly 'traditional' teacher-centred.
Graduate Science course(s). No methods.
Science to age 18 + 1 or 2 years of methods, little or no extra science.
Poorly qualified. Science to age 18. Some school leaving certificate.
Science to age 16 + 1 or 2 years of methods.
Very poorly qualified. Science to age 16.
Level of teacher competence
Material needed in-service course
Teaching competency for Science at a particular level.

Figure 7. A framework for the development of in-service teacher training courses.

Once a particular situation is located in the model, the sorts of instructional units to be included in the in-service sessions can be selected by relating to what training and experience has gone before. The range of units will have to include: (1) science content: 'own' and 'other' fields, (2) ways of unifying science, (3) 'progressive' teaching methods, (4) curriculum, use of existing materials and development of own, (5) nature of learning, (6) attitude change, (7) evaluation and (8) human relations.

To provide models of in-service programmes that have general features of interest, the group drew on the experience of its members.

Mutual teaching, largely *WITHIN-SCHOOL*, was reported to be a successful way of re-orientating experienced subject teachers. If teachers are already competent and confident within their own science subject, it is unlikely that an *AWAY-FROM* school course will be extensive enough to establish new confidence. In this case a preliminary workshop or institute can inspire and initiate a programme that will be worked out continuously over the next term or year as the specialists work together in their school at the task of increasing the integration of their science teaching. They may teach as a team or simply help each other prepare. Continued access to the institute staff for consultation can be an important additional support. Advantages are the high level of commitment and involvement, the continuous support, the close relation of the training to the real task and the optimal utilisation of the educational resources. However, such a programme makes a high time demand on all the participants and does require willingness to work as a team.

Where the conditions allow for more extended *AWAY FROM* school training, a model for such a course was suggested that is based on two generally perceived lacks for teaching integrated science. The first is the formal weaknesses in science subjects other than one or sometimes two fairly specialised areas. The second is inadequate conceptualisation of the purpose, scope and advantage of integrated science teaching itself. Special attention can be paid to both of these in training of the summer institute type. An example was an 8 week course in which the balance was 7 formal hours to 3 hours in the laboratory. In this model it is possible to develop a high level of confidence in the teacher, both in science content and in science education. What he may wish to do will now be clear in general terms but he may feel isolated from other teachers on returning to school. Such a course is often unrelated to the peculiarities of individual schools, and translation to reality may be difficult without support. The courses usually cannot contain actual experience at teaching integrated science and this is another weakness. Williams of Swansea, with this model, avoided the isolation problem by insisting that groups of teachers from a school participate together in the course.

A quite different model lies behind a programme that provides in-service help to teachers in low income countries. In this case the advantages of the *WITHIN* and *AWAY FROM* school models are exploited. A teacher's guide in written form is the first unit in the training. This provides enough detail and support to enable a teacher or the teachers in a school to begin some integrated teaching. At regular intervals, they are visited by a consultant for an intensive 8 hour briefing in the school. Hence the initial attempts can be reviewed and further plans laid in terms of the real situation. Later in the 3-year programme, there are 4-week summer workshops but these can now be used by the teachers as resource for their own particular needs in the light of the experience gained so far. The programme of this model is being used in the West Indies where the teachers' background in both science and modern science education would place them on the lower levels of Figure 7. The written guide makes it easier for new teachers to continue the programme in a school. On the other hand, some teachers do not use the guide in a thorough fashion and for a few it may be a deterrent to self-development.

One final model that is in common use for in-service work is the shorter course *AWAY FROM* the school at a teacher centre which is much less formal than the university or other general teaching institution. These courses need to have quite limited goals such as a confined topic of background knowledge, a unit on organising laboratory work, assessment procedures or familiarisation with one unit of a new science curriculum. The strengths of the centre model lie in its reasonable proximity to schools (e.g. England), its flexibility, teachers' willingness to come, and that schools can be related to its intentions and can make do for short periods. Two weaknesses are the piecemeal nature of the courses and their short sessions which make it hard to diagnose and help the exact problems teachers have in their actual schools.

The Teacher as Evaluator of Student Learning

The evaluative aspect of the science teacher's task has not had much attention paid to it in many instances. Very often evaluation has been identified with terminal examining or ultimate achievement testing and these have usually been in the hands of external examiners or testing authorities. The rather different range of objectives for integrated teaching makes it important for evaluation to be included in the training programmes for teachers. In addition, the very much wider understanding of evaluation that is now available deserves inclusion in any teacher education course in its own right. A 2-step model is given in Figure 8 as a guide to the inclusion of this component in training.

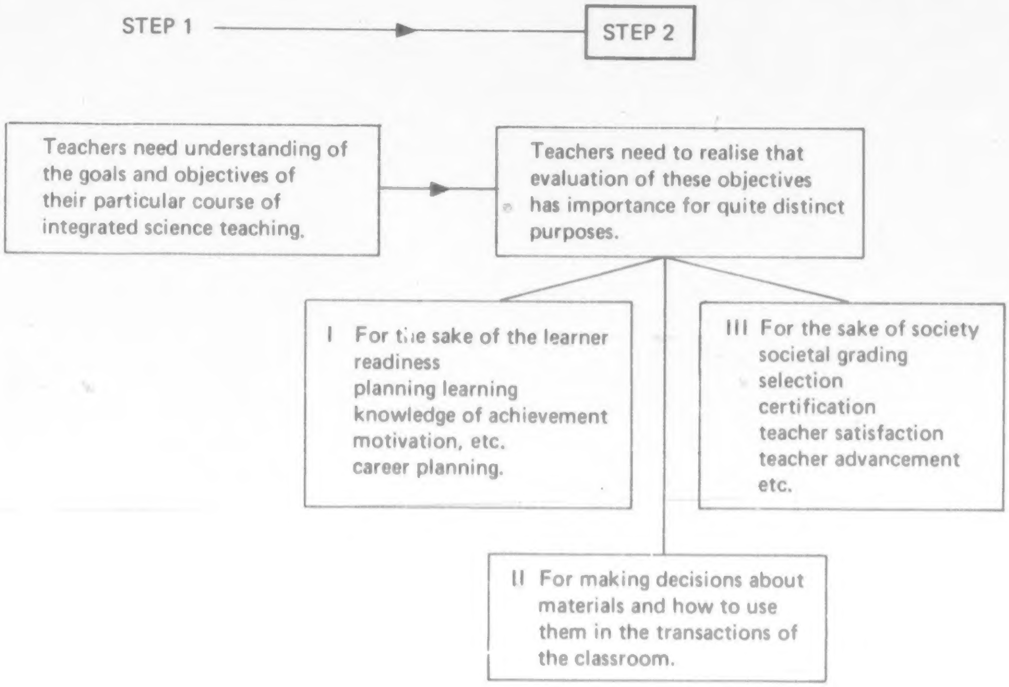

STEP 1
STEP 2
Teachers need understanding of the goals and objectives of their particular course of integrated science teaching.
Teachers need to realise that evaluation of these objectives has importance for quite distinct purposes.
I For the sake of the learner
readiness
planning learning
knowledge of achievement
motivation, etc.
career planning.
III For the sake of society
societal grading
selection
certification
teacher satisfaction
teacher advancement
etc.
II For making decisions about materials and how to use them in the transactions of the classroom.

Figure 8. **A model of the teacher as evaluator of student learning.**

All recent science courses have reflected a movement towards learning objectives that go beyond the factual content of the particular science concerned. The definition of integrated science teaching used at the Conference (see Figure 8 above) stressed generalised concepts, principles and processes and immediately implied a very wide set of cognitive objectives. Many of the integrated science courses are including not only these sorts of objectives but also other more affective ones of a personal and social nature.

The teacher will thus need much help to know what evaluative procedures are most appropriate for this complex range of objectives. Traditional paper and pencil tests will continue to have their use for certain objectives but may be very unsuitable for others. The wide range of possible procedures is unknown to many teachers. For example, oral methods may be very important for scientific literacy and self-evaluation may have its place in some courses that stress initiative, designing investigations and decision making. Because of the radically new emphases in some integrated courses the only meaningful evaluation may in fact be an evaluation of the atmosphere the teacher himself creates in his teaching. If the teacher does not manifest social relevance and concern, it is unfair to expect these in his students. Integrated science teaching continues the stress on student activity and the laboratory that has become familiar in all new science courses. However, its wider emphases may give debating, simulation games, and syndicate work an appropriateness in science teaching that has not been so while disciplines were taught separately.

Consideration of evaluation focussed our attention on a problem that was raised on a number of occasions in the workshop. This is the evaluation of teacher educators themselves. The advancement of integrated science teaching in *all* countries is hindered by this matter. It is particularly a problem in the pre-service sphere since the institutional nature of this work means that the teacher educators may often not be changed or change themselves at the same rate as the innovations are desired in the classroom. This problem is seen to be so important that the next section is devoted to the report of a special sub-group. We commend it for consideration as basic to the whole topic of the Conference.

Oral work, self-assessment and a diverse range of evaluative procedures are not, and have not, in general, been part of the educational experience of most science teachers. Without such personal experience it is hard to expect teachers to start using them.

Test construction and elementary statistics are common, but by no means universally accepted components of teacher preparation. For the objectives of integrated science, acquaintance of the significance and limitations of these topics become essentials for teachers. The S.C.I.S.P. probably exemplifies the best range of evaluative procedures at the present time and these are most valuable resources for use in teacher education.

The Re-education of Teacher Educators

The teacher educator, himself, is in many instances orientated to single science disciplines, and accordingly conveys the substance of his discipline as though the others do not matter. Integration is left to the students, and this rarely occurs.

Furthermore, education and science specialists, entrusted with the task of preparing teachers to teach children, sometimes visit but rarely take on the task of teaching young people in elementary or secondary schools. An experience of teaching children early in their own career is considered to have qualified them to prepare teachers forever. Changes, of course, have occurred in students – in their expectations, motivations and values, – in facilities and equipment, in curriculum and in society. It is essential that teacher-educators are required to return to the schools periodically to teach; a contact of a couple of weeks each year would provide a basis for realism, and give their teacher-trainees confidence in them. The first hand experience will make the trainers aware of the learning difficulties which children face, and the teaching difficulties which teachers encounter. They will be sensitized to the out-of-school influences such as neglect, hunger and other deprivations that interfere with teaching and learning. While these conditions exist in pockets in developed countries, it is a more general and serious problem in the under-developed ones.

In addition to this involvement with the realities of the classroom, it is important that teacher educators should repeatedly acquaint themselves with the realities of the effect that science and technology have, or could have, on the society in which they live. Means need to be found to involve science educators in social situations where decisions about scientific matters are being made. Key scientific innovations, either technologically or educationally, are few in number in most societies. It is important, therefore, that ways be found to include contributions from them in the regular programmes of training institutions.

It may seem axiomatic that a teacher for the integrated approach should be trained by experiences similar in kind to those he is expected to use. However, present practice is very far from this situation. Through involvement of the teacher educators in first hand experiences of the type we have outlined it is likely that they will appreciate the complex, competitive and often confusing and hostile environments in which teachers have to work. They may then seek other means of doing their own teaching of teachers.

The Role of Education Officers and Administrators in the Preparation of Teachers

The primary focus of this section is the role of educational administrators. However, these are only part of a wider set of external factors that affect the outcomes of programmes to train teachers of integrated science. The set contains a great variety of elements – policy makers, headmasters, other teachers, inspectors, teacher unions, professional societies, examination systems – particularly for university entrance, parents and budget controllers. Which ones will have more major roles will depend on the particular local situtaion in a given country. Examples of the way these roles have been exercised in actual cases were considered and it became clear that all have the potential to make a positive or a negative contribution in relation to the teaching of integrated science.

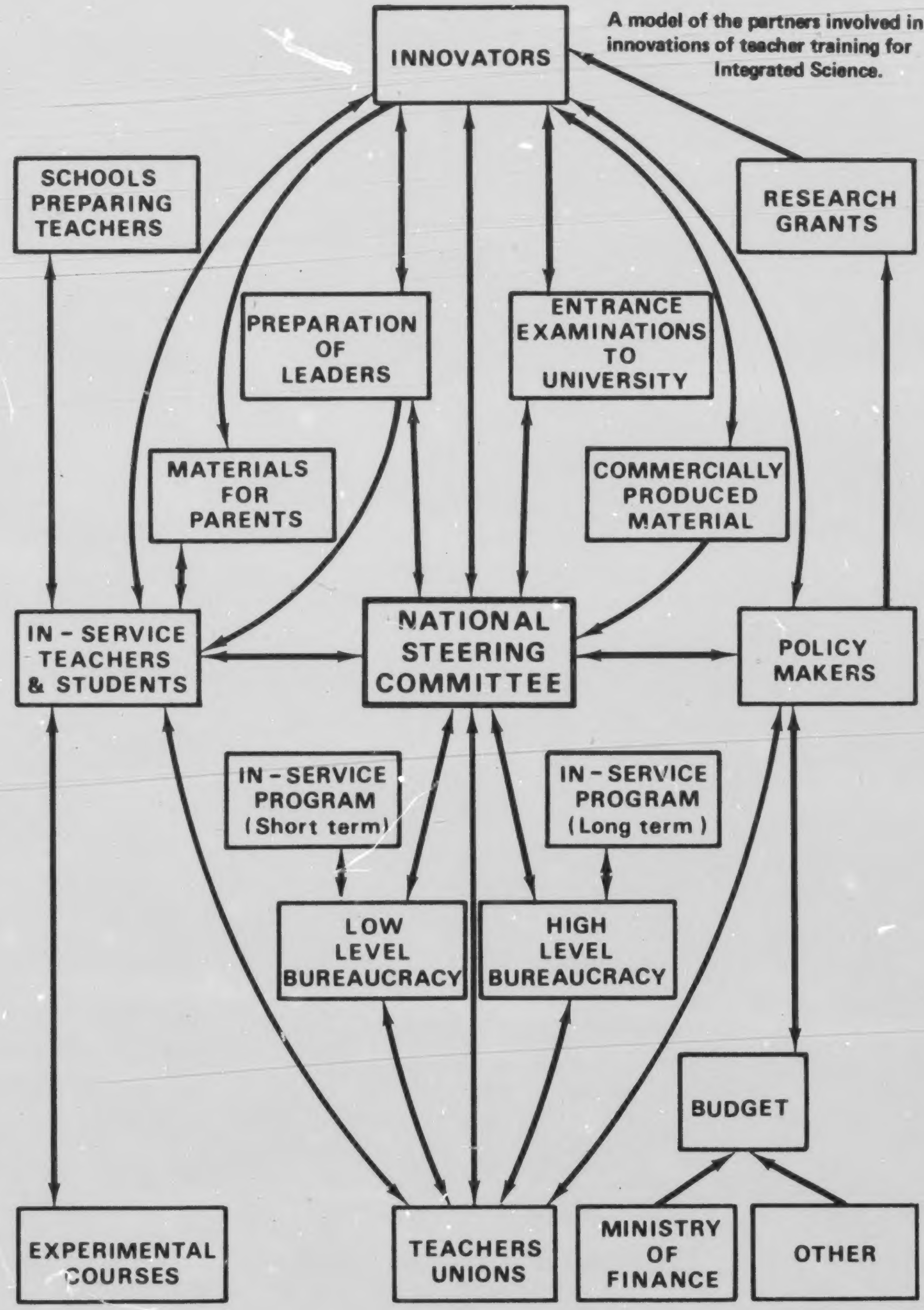
Figure 9 is a model of the ways in which all these elements can interact with each other. A National Steering Committee has been placed in the centre of the model to emphasise that the training of teachers for integrated science teaching is not a task to be undertaken lightly if we want it to succeed.

Changes in established roles and accepted patterns are involved in the move to integration. This is not an activity to be grafted on to existing structures of science teaching but a transformation of the present to some new form. Such changes require support from the great variety of bodies listed and shown in Figure 9. Unless adequate communication is maintained at each step of the programme, the negative potentials of various elements will show themselves and seriously impair the innovation.

However, more than communication is needed. Action and response from the various elements will be required for successful outcomes of a training programme. While teachers are being trained it is important to prepare parents for the new courses their children will soon study. None of these parents will be familiar with what is being attempted. This is also true of most other persons in these interactive elements, other than the innovators and those directly involved in the training programme. Before the programme is launched much careful work must be done

Figure 9.

A model of the partners involved in innovations of teacher training for Integrated Science.


INNOVATORS
SCHOOLS PREPARING TEACHERS
RESEARCH GRANTS
PREPARATION OF LEADERS
ENTRANCE EXAMINATIONS TO UNIVERSITY
MATERIALS FOR PARENTS
COMMERCIALLY PRODUCED MATERIAL
IN-SERVICE TEACHERS & STUDENTS
NATIONAL STEERING COMMITTEE
POLICY MAKERS
IN-SERVICE PROGRAM (Short term)
IN-SERVICE PROGRAM (Long term)
LOW LEVEL BUREAUCRACY
HIGH LEVEL BUREAUCRACY
BUDGET
EXPERIMENTAL COURSES
TEACHERS UNIONS
MINISTRY OF FINANCE
OTHER

by the National Steering Committee and the innovators to ensure that adequate funds and other support is forthcoming from ministries, unions and universities. Before and during the training, through other forms of in-service activity, it is important that headmasters and fellow teachers be helped to understand the nature of the new approach and what it will need by way of support in the school.

Summary

The reports of the working groups of this Conference discuss detailed aspects of many of the models we have proposed. One last model can be used to sum up our own deliberations. The outcome of our teacher preparation programmes is to be *TEACHERS TEACHING PUPILS INTEGRATED SCIENCE.* Each component of this intended outcome must be covered by our programmes and Figure 10 reminds us of this task.

TEACHERS	TEACHING	PUPILS	INTEGRATED SCIENCE (I.S.)
Own Science Education Attitudes to Science Perception of teaching Science Models for teaching Sense of Person in Education Social responsibility	Styles for I.S. Practical skills for I.S. Organisation for I.S. Teaching and individual differences Assessment in teaching	Characteristics Background Future needs Development and learning Learning methods Assessment and learning Social responsibility	Substance and syntax of I.S. Aims and goals of I.S. I.S. in whole curriculum I.S. – Maths I.S. – Other Sciences I.S. – Social Sciences

Figure 10. **Summary model of the objectives of the training task.**

REFERENCE

1. **International Commission of Scientific Unions**, 'The Education of Teachers for Integrated Science – Report', ICSU, London, 1973.

MATERIALS FOR TRAINING TEACHERS TO TEACH INTEGRATED SCIENCE

Report of Working Group Wb.
Chairman: Clive Sutton, University of Leicester, U.K.
Rapporteur: Edith A. Müller, Observatoire de Genève, Switzerland.

Preamble

Who trains teachers? . . . College tutors? . . . Inspectors and Advisers? . . . Teachers themselves in small groups? . . . or individual teachers working and studying on their own?

Are there enough materials to support each of these training situations? Are the Teachers' Guides to published courses in integrated science sufficient?

The materials that a tutor, or any other course organiser uses will depend on his theory about what is happening in the process of teacher training. For example, if your theory is simply a *familiarisation theory* ('trainee teachers should handle the pupils' materials, try out experiments, and all will be well'), then you may regard the pupils' books and apparatus, together with the Teachers' Guides, as sufficient. If however your theory is one of *role change* in the teacher ('teachers will only change their behaviour in the classroom if they perceive their role in a new way'), then the training procedures will have to put the teacher in new roles, and a different kind of material will be required. The teachers may have to be immersed in the kind of activities and thinking processes it is hoped that they will encourage in their pupils, so that they may pick up the approach, and later apply it in their own schools. If the required new roles of the teacher include more professional decision-making, then the training procedure should perhaps involve him in making decisions about the curriculum and teaching methods. With such an approach the appropriate materials could include case studies and simulation exercises to provoke small group discussion. The simulation and discussion technique is an established method for changing attitudes and assisting professional development in the training of managers and social workers, though perhaps not yet in the field of teacher training.

In summary, it appears that there is now quite a lot of material for the training of teachers of integrated science if one is working according to a *familiarisation theory,* but there is very little if one is working according to a *role change theory.*

During the Conference the Working Group studied some of the material that is available now, and discussed how the material can be incorporated in courses and what additional material is needed.

For efficient working, the materials were divided into the following types which were investigated by separate teams:

(i) Apparatus.

(ii) Printed course material for elementary and middle school teachers (middle school = junior secondary).

(iii) Printed course material for secondary school teachers.

(iv) Audiovisual materials.

(v) Aids and guidelines for organizing teachers' courses.

In this Report examples of available material are given with information about how to get it. Furthermore, it is pointed out (at least for some categories) what else is needed and how it might be obtained.

I. APPARATUS

A. *Available Apparatus*

The adoption of integrated science has obvious implications for the provision of apparatus both for pupils and for teachers in training. The most important of these is that scientific apparatus in the traditional sense is secondary in significance to the exploitation by the teacher of the particular environment in which he is teaching.

Another point worthy of mention is that apparatus designed specifically for teacher education for integrated science, as opposed to that designed for the use of pupils but important also in teacher-training, will not be very different.

In the collection maintained by the International Clearinghouse at the University of Maryland, there are examples of:

(a) Newly developed, low cost, single items of apparatus, e.g. drinking straw balances, simple electric motors, etc.

(b) Self-contained kits of apparatus such as those developed by FUNBEC in Brazil (available from FUNBEC, Caixa Postal 91, Sao Paulo, Brazil) or the NCERT (National Council for Educational Research and Training, New Delhi, India).

(c) Whole programmes in integrated science which incorporate their own apparatus, e.g. SCIS (The Lawrence Hall of Science, Univ. of California, Berkeley, Calif., U.S.A.).

(d) Equipment not specifically designed for teaching, which can be obtained from local markets, e.g. toys and kitchenware adapted to science experiments. (See § C. below).

(e) Equipment which can be made by teachers as part of their training. Note, however, that the school science teachers should not be *expected* to make their own equipment. (See § B. below). Good sources of ideas on this are the UNESCO Sourcebook for Science Teaching, and the International Clearinghouse Resource Book.

(f) Ideas for using traditional apparatus in new ways. E.g. the ball and ring apparatus for studying expansion of metals can be related to local wheel-making industry in Asia if the ring is heated instead of the ball. (Note that in cool conditions the ball will not pass through the ring).

There is a lot of apparatus available. The main problems, however, are (1) the choice and selection for particular approaches and particular situations, and (2) the lack of knowledge of how to use existing apparatus.

B. *Teacher Training and the Use and Design of Equipment*

The teacher's role in the development of teaching aids is important, but it should be strongly emphasized that it is not realistic to rely on teachers for the supply of science and mathematics apparatus for the school system in general. The heavy and continuously increasing teaching load, the lack of workshop facilities, and a multitude of other factors make it difficult, or rather impossible for the science teacher to fabricate equipment in any reasonable quantities.

It should be emphasized that the teacher training institutions must be equipped with apparatus the teacher will encounter in the school itself. Besides this, there must also be additional equipment to enable the teacher to gain more knowledge and to discover other ways and means to demonstrate or teach a particular subject matter. The use and handling of equipment by the student teacher must be stressed during his initial training so that he, in turn, will encourage such activities in his school.

It is also desirable to include design and fabrication of simple science teaching equipment in the pre-service and in-service courses for teachers. This activity will help the teacher to read and understand a simple manufacturing drawing, and will enable him to make a legible drawing of apparatus he wishes to have manufactured in a school workshop or by local craftsman. Furthermore, practical training in equipment making and the use of common hand tools is always an asset particularly in cases where the schools do not have a technician available and the teacher must maintain the equipment and carry out minor repairs himself.

Examples of how to engage teachers in building simple apparatus are given by the 'Science Teacher Education Project' (STEP) in *Activities and Experiences*, McGraw Hill, 1974, and by the 'Teacher Initiated Project' (TIP), Lawrence Hall of Science, Berkeley, California. Further information can also be obtained from the following publications:

(a) 'Design and Construction of Low-cost Science Teaching Equipment', International Clearing House, Science Teaching Centre, University of Maryland, College Park, Md., U.S.A.

(b) UNESCO Source-book for Science Teaching.

(c) 'Making Elementary Science Apparatus', by M. K. Bowker and A. R. D. Hunt, Thomas Nelson and Sons, London.

(d) 'Construction and Use of Simple Physics Apparatus', by R. F. Simpson, Department of Education, University of Hong Kong, Hong Kong.

(e) 'The Use of Low-Cost Material, Everyday Items and Locally Constructed Apparatus for Teaching Integrated Science' in New Trends in Integrated Science Teaching, Volume 2, UNESCO, 1973.

C. *Low-cost equipment*

Student orientated curricula are demanding large quantities of equipment. To meet this demand, new types of 'low-cost' apparatus must be developed or, if possible, obtained from hardware stores and bazaars. This type of equipment can be classified as 'informal', as it is not specially designed or intended for science teaching. It is usually inexpensive since large quantities of items are manufactured for commercial use.

A second type of 'low-cost' equipment is teaching/learning materials which can be produced from locally available raw materials, such as wood and metal components manufactured indigenously. Local plastics manufacturers should also be utilized for large scale production of plastic articles made by injection moulding or vacuum-forming techniques. Typical samples of 'low-cost' teaching/learning materials can be found in publications such as:

(a) 'Specification and Manufacturing Drawings for Science Equipment', NCERT, New Delhi, India.

(b) 'Nuffield Guide for Construction of Science Teaching Equipment', Chelsea College Centre for Science Education, Bridges Place, London, S.W.6., United Kingdom.

(c) Various science curriculum development projects in the United States of America, such as SCIS (Science Curriculum Improvement Study), IPS (Introductory Physical Science), ISCS (Intermediate Science Curriculum Study), PSNS (Physical Science for Non-Science Students), AAAS (Science – A Process Approach), and SSSP (Secondary School Science Project).

It is important that local manufacturing facilities are established for the provision of low-cost equipment. Only a country's own efforts can provide the necessary materials for a better and more effective educational system. It should be pointed out, however, that no country can economically manufacture all component parts needed for science equipment. A certain quantity of items will have to be imported. Items such as magnets, bearings and electronic components are perhaps cheaper imported than manufactured. It will, therefore, be necessary to establish a system whereby certain imports can be arranged and channelled into the manufacturing of school equipment.

In Asia, for example, several countries have established school science equipment manufacturing units for production of low-cost equipment, utilizing local raw materials and technology. Presently, Burma, India, Sri Lanka and Turkey have manufacturing facilities which produce school science equipment in large quantities. Afghanistan, Bangladesh, Indonesia, Republic of Korea, Malaysia, Nepal, Pakistan, and the Philippines are producing on a limited scale or are in the process of establishing such centres so that low-cost equipment for students' use can be supplied to the many schools now lacking teaching aids for science and mathematics.

D. *Suggested Design Criteria*

For the selection of equipment it is necessary to have some design criteria and guides available and it is important to apply these before design and procurement of any equipment. The following design criteria are suggested:

1 – Depending on the needs, ideas should be initiated from the curriculum development centres or other institutions where new curricula for science teaching are established. Parallel with the textual material, ideas for the development of science equipment should emerge.

2 – Apparatus used for science teaching should be 'transparent' in other words an instrument should clearly show the scientific principle involved. 'Black boxes' should be avoided, particularly so with student centred curricula.

3 – 'Educational Prototypes' must be developed and evaluated at suitable trial schools and subsequently modified if found defective.

4 – If the instrument has been found to be educationally satisfactory, an industrial model may now be designed. At this stage consideration should be given to material, tolerances, quality and production methods so that the manufacturing cost can be kept to a minimum.

5 – In designing teaching/learning material attention should be paid to the appearance of the equipment particularly so when the equipment is to be used by younger children.

6 – In design of equipment for primary and lower secondary levels principles should be emphasized rather than accuracy of the results.

E. *Suggested Code of Practice for the Procurement of Apparatus*

The discussions of the Working Group lead to the following suggestions concerning the procurement of science teaching equipment:

1 – Decisions should be made for obtaining apparatus with the direct participation of professional teacher educators.

2 – Purchase of equipment must be directly related to the plans for training and use.

3 – Items of apparatus designed for given programs should, as far as possible, be manufactured or assembled in local manufacturing centres or industries closely associated with the development of the programs.

Information regarding existing production units in developing countries can be obtained from UNESCO Regional Offices, e.g. Bangkok (Asia), Dakar (Africa) and Santiago (South America).

A suggested general system for the design, production and distribution of school science equipment is shown on Chart 1.

II. PRINTED COURSE MATERIALS FOR ELEMENTARY AND MIDDLE SCHOOL TEACHERS

A. *Available material*

The following notes are confined essentially to materials found in the International Clearinghouse Exhibition at the University of Maryland, and to sections of them which appeared to the Working Group to be particularly helpful.

The name of the project is given in capital letters, and the titles of relevant books are underlined. The page numbers in parentheses, if listed, refer to the Eighth International Clearinghouse Report, 1972 (editor J. D. Lockard), where further details are given including the addresses from which these books may be obtained.

THE AFRICAN PRIMARY SCIENCE PROGRAM (APSP) (pp 29 – 33)

This project has prepared a series of monographs as follows:

Making a Start; Origin and Development; Administration; Teacher Training; Unit Construction; Evaluation of the APSP. The monographs give accounts of first hand experience of work in primary schools in Africa. They are written in a simple, direct, compact form.

A relevant book prepared by this project is:

In-Service Training of Teachers by R. W. Carlisle. It gives an account of practical experiences of current in-service courses in Africa, with a review of the component elements of such workshops.

THE SCIENCE EDUCATION PROGRAM FOR AFRICA (SEPA) (pp 45 – 47)

The publications of this project include:

(a) *Science Teachers' Associations of Africa*

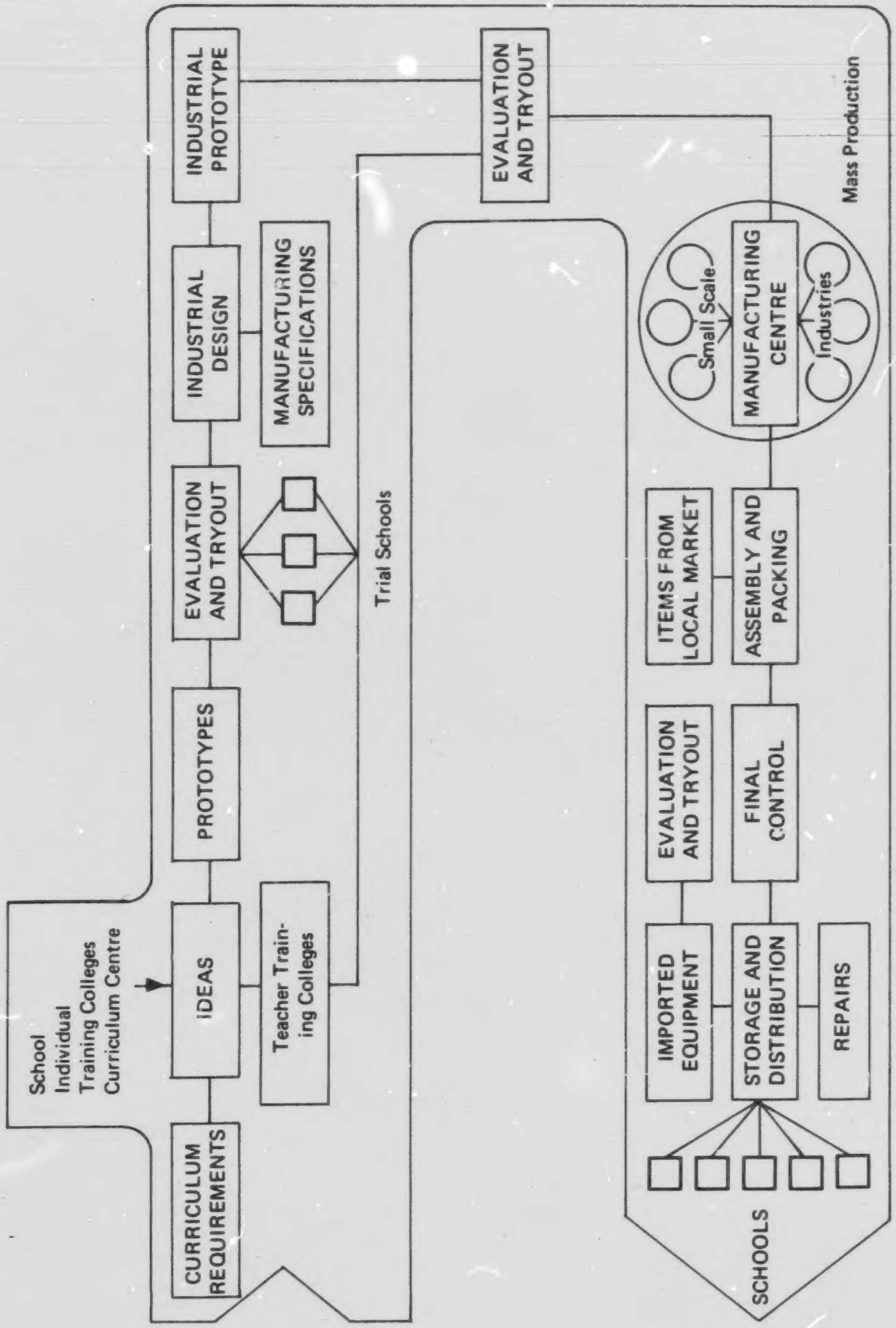
A statement of the aims and organization of teachers' centres in Ghana, Nigeria, Swaziland and Zambia.

(b) *Teacher Training Materials Workshop, 1971* (Nairobi, Kenya)

This gives an overview of topics that would be of value to those concerned with such activities in Africa.

Chart 1

SUGGESTION FOR A GENERAL SYSTEM FOR THE DESIGN, PRODUCTION AND DISTRIBUTION OF SCHOOL SCIENCE EQUIPMENT


CURRICULUM REQUIREMENTS
School
Individual
Training Colleges
Curriculum Centre
IDEAS
Teacher Training Colleges
PROTOTYPES
EVALUATION AND TRYOUT
Trial Schools
INDUSTRIAL DESIGN
MANUFACTURING SPECIFICATIONS
INDUSTRIAL PROTOTYPE
EVALUATION AND TRYOUT
Mass Production
Small Scale
Industries
MANUFACTURING CENTRE
ITEMS FROM LOCAL MARKET
ASSEMBLY AND PACKING
EVALUATION AND TRYOUT
FINAL CONTROL
IMPORTED EQUIPMENT
STORAGE AND DISTRIBUTION
REPAIRS
SCHOOLS

SCIENCE – A PROCESS APPROACH (of the American Association for the Advancement of Science) (SEPA/AAAS) (pp 787 – 792)

Some of the most useful booklets prepared by this project are:

(a) *Commentary for Teachers*

This booklet deals with the chronology of the project development, lists and comments on the process, and it also gives some details of the evaluation. Furthermore, reference is given to ten science background papers useful for those involved with the training of teachers (self-instructional material, resource book for teachers).

(b) *Guide for In-Service Instruction*

An introduction for a process approach to science teaching. It refers to the SEPA project but it is, in addition, useful for the training of teachers who wish to use a process approach in their integrated science lessons.

(c) *Science Process Measure for Teachers*

Tests and instruction for evaluation of the SEPA approach.

(d) *An Evaluation Model and its Application* (2 volumes)

Background information concerning the rational development and evaluation of the SEPA curriculum. Useful for the education of teachers who are encouraged to participate in the revision of SEPA and other curriculum work. The definition of behavioural objectives may influence the teaching style.

(e) *Materials and Equipment*

Information for the teacher concerning the materials for single experiments and organized in terms of the underlying processes of SEPA, together with hints for the performance of the experiments in the classroom situation.

Note also that the AAAS which financed the SEPA project has published two booklets on guidelines and recommendations called:

1 – *Pre-service Science Education of Elementary School Teachers*
(AAAS Miscellaneous Publication 70–5). and

2 – *Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics.*
(AAAS Miscellaneous Publication 71–9).

COLLEGE CURRICULUM SCIENCE STUDIES PROJECT (CCSSP)

Southlands College of Education, London S.W.19 5NN, United Kingdom.

This project aims to produce activity units to give students and teachers support in teaching science by giving background in broad areas and dealing with specific points of general relevance to teaching primary science. The self-instructional modules of work help the student teachers to increase their confidence in tackling scientific topics.

THE AUSTRALIAN SCIENCE EDUCATION PROJECT (ASEP) (pp 128 – 132)

The relevant publications are:

(a) *Introduction to ASEP*

This is for use as part of a teacher education course or a guide to retraining by individual study or by conference.

(b) *ASEP Units and their use*

It describes the content and structure of the project's publications.

(c) *The ASEP Handbook*

Shows how a curriculum can be developed and discusses the process of learning.

SCIENCE 5/13 PROJECT (Schools Council London) (pp 260 – 263)

The booklet *With Objectives in Mind* (published by Macdonald, London) provides the desired motivation to teachers by clarifying basic ideas and issues connected with the 'how' and 'why' of the integrated approach to science for children. It is a clear statement of how a set of objectives could be devised.

The other booklets published by this project provide guidance for teachers on activities with wood, trees, metals, toys, small animals, etc. They are exceptionally well illustrated with examples of pupils' work.

THE INTERMEDIATE SCIENCE CURRICULUM STUDY (ISCS) (pp 647 – 650)

The following booklets are relevant and emphasize the pedagogy:

Rationale for Individualization; Classroom Organization; Questioning; Your Students' Role; Evaluating and Reporting Progress.

These instructional modules have been designed in an individualized and self-paced format for use independently by either pre- or in-service teachers, or by teacher-educators working with teachers. They place the teachers in much the same role as their student will be in, if they teach the ISCS materials. Each module contains many ideas and suggestions on how to teach any program in an individualized and self-paced setting.

Similar modules dealing with the content of science include the following titles: *Operationally Defining Work; Measuring Electricity; Heat and Particles; Science Concept – Work; Science Concept – Electrical Energy; Science Concept – Energy and Systems.* (Publishers: Silver Burdett, New Jersey). The modules are written for the teacher. The format is individualized and permits self-pacing. They are useful for anyone wishing to develop an understanding of the science content described.

The publication *Preparing the ISCS Teacher* (1970) is designed to help science supervisors and professors of science education to plan instructional programs for teachers who will be using the ISCS materials. It contains many ideas and suggestions generally applicable to initiating and implementing any individualized and self-paced program.

FUNDAÇÃO BRASILEIRA PARA O DESENVOLVIMENTO DO ENSINO DE CIENCIAS (FUNBEC) (pp 396 – 397)

In the present context the following publication is of particular interest: *Guia do Professor para o Ensino de Ciencias no Curso Primerio* – Vol. I, pp 1 – 5. It concerns elementary school teaching and it includes the objectives and methodology to follow for this particular program.

NUFFIELD COMBINED SCIENCE, 11 – 13

These books are published by Longman/Penguin in the U.K. The following sections are particularly relevant:

1 – Teachers Guide, Vol. I, Foreword, pp XI – XV.
2 – Teachers Guide, Vol. I. Appendix II, pp 407 – 409.
3 – Teachers Guide, Vol. II, Appendix II, pp 363 – 371.
4 – Teachers Guide, Vol. III, all of this book.

The first of these references gives a description of the Combined Science Project, principles involved in the general aim, ways of working in the classroom, and suggestions on how to adapt the scheme for children of varying ability. The second includes comments and methods for teachers who work with slow learners (realistic information). The third gives suggestions for ways of assessing children's reactions. Although intended for the Combined Science Project it serves as an example for other projects. Finally, the fourth reference is a useful source of hints and practical tips covering all aspects of the background for Combined Science. It also includes a complete list of all books, apparatus, films and filmloops.

THE SCOTTISH INTEGRATED SCIENCE SCHEME

The *Curriculum Paper No. 7, Science in General Education* (Published by the Scottish Education Department and H.M. Stationery Office) provides a concise and itemized overview of integrated science aims and methods with particular reference to Scotland. Since, however, the approach has been adopted in other countries this document is of particular significance for the training of teachers of integrated science in many countries.

Related books, entitled *Science for the Seventies* are published by Heinemann in the U.K.

OTHER RELEVANT BOOKS ARE:

1 – *Environmental Studies Project,* published by the Schools Council London. It provides back-up reading for teachers interested in environmental studies.

2 – *Bicycles to Beaches,* by Gillespie, Brough, Curtiss and Gornall (Canada, McGraw Hill Ryerson Ltd.) (Internat. Scient. Book No. 0–07–077372–6). In this book the pages 119–147 should give primary teachers enough confidence to teach science.

B. *What else is needed?*

Slide tape presentation and program texts are suggested as areas which need development, to enable teachers at different levels to familiarize themselves with the general content of science, the particular approach of an individual project, and ways of teaching such material.

The SCIENCE TEACHER EDUCATION PROJECT (STEP) (pp 264 – 266) in the U.K. has developed self-instructional kits entitled *Getting to know Science 5/13, Finding out about Nuffield Combined Science,* and *Getting to know SCISP.* These, and the self-instructional materials for teachers trying to familiarize themselves with the ISCS Project provide examples of a format in which many more projects might present themselves.

III. PRINTED COURSE MATERIAL FOR SECONDARY SCHOOL TEACHERS

A. *Available Material*

As in Section II some of the relevant materials which were considered to be particularly useful, are listed below. The same annotations are employed.

AUSTRALIAN SCIENCE EDUCATION PROJECT (ASEP) (pp 128 – 131)

The ASEP materials include instructions for students, information for teachers, audio-visual materials, charts, resource materials, guides for experimental investigations, classroom aids and assessment devices.

The materials are designed to help the teachers provide learning experiences for students in such a way that differences in teachers' interests, and teachers' and students' abilities will be catered for. The materials are strongly committed to an inquiry approach to help students understand their environment.

The materials are collected into units. They are sufficient in quantity to satisfy a major portion of the requirements for courses in secondary school science (ages 14 – 18).

A BRAZILIAN PROJECT

For the preparation of science teachers of secondary schools (ages 13 – 18) a series of books were prepared, entitled *Como Ensinar Ciencias*, by O. Frota-Pessoa, R. Gevertz and A. Gonçalves da Silva (Editora da Universidade da Sao Paulo e Comp. Editora Nacional, Sao Paulo, 1970). The series of 10 books consist of the following volumes:

1 – One book giving the methodology of the series;

2 – Four books are texts in integrated science for the students;

3 – Four books are the corresponding teachers' guides;

4 – One book describes special projects to be developed by the teachers.

This project is being used in the Schools of Education, in the Faculties which offer courses in science for teachers, and for the in-service training of science teachers.

SCIENCE EDUCATION IMPROVEMENT PROGRAMME IN JAPAN (Japanese Ministry of Education)

This programme has developed a one-year basic science course taught from an integrated science approach. It is intended for students at 10th grade level (U.S. system), i.e. two years before entering university.

The concepts studied are the following: Energy and its changes; Relationships between light and substances; Structure of substance and chemical reaction; Broad expansion of the universe; Maintenance and continuation of life; Evolution of the Earth and living things.

Four textbooks and corresponding teachers' guides are available. They are written in Japanese. The programme is being evaluated by studying the experience gained in two pilot schools. The teachers themselves are trained at Science Education Centres.

NUFFIELD SECONDARY SCIENCE PROJECT(pp 238 – 240)

The program is designed for children of ages 13 – 16 years taking non-academic courses. The project has developed materials from which the teachers can plan and construct courses for their students. The contents of the materials are so chosen that they are relevant to the daily life of the learners. It is the responsibility of the teachers to establish the significance of what is done in the classroom to the learners' daily life. Therefore, the material is useful for training science teachers.

SCHOOLS COUNCIL INTEGRATED SCIENCE PROJECT (SCISP), published by Longman and Penguin, 1973, in the U.K. (pp 247 – 250)

This project has produced materials designed to be used for academically able children of ages 13 – 16 years. Apart from the pupil's manuals and background books the program has also developed materials specifically for the teacher's handbook, manuals, tape/slides and brochures.

The teacher's guides are so designed that groups of teachers can conduct their own in-service training in each school that has decided to use the program.

Case studies developed by the project describe how schools are using the program.

Tape/slide materials called *Integrated Science in Action* were also produced. They show how teachers are tackling the task of using the program in their schools.

A brochure entitled *Getting to know Integrated Science* contains simulation exercises that can be used by teachers so as to get them involved in using the program.

SCIENCE, TECHNOLOGY AND SOCIETY MODULES (American Assoc. for the Advancement of Science (AAAS), Washington, D.C. U.S.A.).

The modules were developed by groups of teachers and students in the Montgomery County (Maryland, U.S.A.) Public Schools in collaboration with the AAAS. The following topics are included in the modules: Science, Technology and Privacy; Genetic Engineering; Behaviour Modification; Energy and the Quality of Life. The modules are designed to be used by both science and non-science teachers.

B. *What else is needed?*

Similar remarks may be made here as in Section II under the same heading. The production of simple and clear self-instructional material for teachers is very important.

It was highly recommended that each country should develop its own materials according to its needs. One should avoid imposing a program which may be good in one country onto another country. However, all good and useful materials from various countries should be secured to provide background, examples of good practice and even pilot testing for the work of local science education groups in any country.

It also was stressed that science teaching centres should be established in developing countries. These centres should be used not only for teacher training programs but also for creating new materials on integrated science according to the real needs of each country. These centres should be autonomous.

IV. AUDIO-VISUAL MATERIALS FOR THE TRAINING OF TEACHERS IN INTEGRATED SCIENCE

As far as the Working Group knows, very few audio-visual materials are available which are specifically designed for training teachers in integrated science.

The feasibility was considered of using existing materials, originally designed for the teaching of separate disciplines, to convey the ideas behind integrated science. In teacher training, audio-visual materials are particularly useful in the following main areas:

(a) giving background information on integrated science for the teacher,

(b) showing the methodology of the teaching of integrated science.

Audio-visual materials are needed not only for training teachers but also for gaining (a) the support from the community at large, and (b) the acceptance of innovation within the educational system. Television could be used quite efficiently in promoting the integration ideas through the educational system.

The audio-visual materials to be developed should present situations in which real integration has been accomplished at various levels to different degrees, thus demonstrating its feasibility.

Table 1 shows in which ways the audio-visual materials could be used in teachers' training.

Table 1 THE USE OF AUDIO-VISUAL MATERIAL IN TEACHERS' TRAINING

Audio-Visual Material	Contribution	How can it be incorporated in teachers' training?
A. Films (a) Science films in different scientific areas.	Demonstrating science as an integrated discipline. Passing to the teachers the *idea* of integrated science. Showing learning situations as models or as a basis for discussion.	(1) Teacher courses. (2) Television (using the mass media).
(b) Films dealing with methods of teaching integrated science.		(1) Teacher courses. (2) Television showing a group of experts discussing classroom situations.
B. Video Tapes		
(a) Taken in class.	Analyzing ways of behaviour of teacher and pupils, or presenting technical problems existing in teaching integrated science.	Teacher courses.
(b) Taken in teacher courses.	Teacher analyzing his own behaviour.	Teacher courses
(c) Film Loops presenting phenomena.	Discussing and designing an integrated unit around the phenomena shown.	Teacher courses and work sheets.
(d) Slides or transparencies and tape recorder	Understanding the unit of integrated science to be taught.	Can be used for group training or self-teaching in the way of individual instruction.

V. AIDS AND GUIDELINES FOR ORGANIZING TEACHERS' COURSES

A. *Available Material*

A number of teacher training groups have produced useful materials. Some of them are listed with brief comments in Sections II and III such as SEPA/APSP, ISCS, SCIENCE 5/13, STEP in Section II and SCISP in Section III.

Some additional information is given below which illustrates different outlooks in teacher training.

- The SCIENCE UNIT, Accra, Ghana, published a booklet entitled *Some Suggestions on Running Science Workshops* by J. Seawell and J. Kusi-Achampong. In this booklet suggestions are made about the timing and organization of workshops, the selection of participants and the follow-up visits and work.
- The ASSOCIATION FOR PRODUCTIVE TEACHING (5408 Chicago Ave., S., Minneapolis, Minnesota, U.S.A.) has a basic resource book called *The Role of the Teacher in the Classroom*, by N. A. Flanders and E. J. Amidon.
- The CENTRE FOR UNIFIED SCIENCE EDUCATION (CUSE) (1460 W. Lane Ave., Columbus, Ohio, U.S.A.) recommends a module approach as a model for teacher preparation.
- The book *Teaching of Physics – an Insoluble Task* by E. J. Werkom (M. I. T. Press 1972, U.S.A.) describes experiences in planning in-service training courses for experienced teachers of secondary school science.
- The COLLEGE CURRICULUM SCIENCE STUDIES PROJECT (CCSSP) (Southlands College of Education, London S.W.19 5NN, U.K.) produced units for student teachers guiding them in simple practical activities from which they may gain confidence and, at the same time, deepen their knowledge in science which they ultimately carry into the classroom. Example: *The Aerial Cable Car.*
- The SCIENCE TEACHER EDUCATION PROJECT (STEP) mentioned briefly in Section II, provides a number of tested, self-contained curriculum units for student teachers from which a selection may be made in the development of a course for the professional preparation of science teachers. The materials are concerned not with the content of science but with pedagogy, i.e. methods of teaching science, and some aspects of it are related to psychology, sociology and philosophy. They are published by McGraw-Hill in the U.K. under the following titles:

  1 – *Activities and Experiences* – a source book for tutors giving numerous ideas for planning courses in colleges and universities.

  2 – *Theory into Practice* – activities in school for student teachers.

  3 – *Meadowbank School* – case studies in education.

  4 – *Through the Eyes of the Pupil* – a collection of pupils' writings to help student teachers to put themselves into pupils' shoes.

  5 – *Readings in Science Education* – some extracts from important papers and books, gathered into one collection.

  6 – *The Art of the Science Teacher* – a book for teachers and student teachers, surveying the main aspects of professional studies.

  7– *Innovation in Teacher Education* – a short description for tutors describing the aims of the Project, the choice of method, student motivation, content of a methods course, and methods of evaluation.

B. *What else is needed?*

The Working Group gave quite some thought to the question on what new materials might be desirable and could be developed for training teachers of integrated science. The materials should give outlines on what to do in teacher training programs, in-service institutes, etc. They should however, not be confined to any specific curriculum project.

The Working Group reached the following conclusions and made the following recommendations on the desirable future developments:

1 – *A monograph, prepared internationally,* giving guidelines on the production of teacher training materials, would be of assistance to teacher trainers in many countries. Such a monograph could help to ensure that student teachers understand what is meant by integrated science in a functional manner: by analyzing and providing examples, and by describing the teacher training methods used in introducing courses of integrated science in particular countries. It should collect the best available ideas on the kind of experiences which will develop in the student teacher that confidence and sensitivity which will enable him/her to meet the challenge of integrative teaching. It should provide practical guidance on how to organise teacher training courses, and how to prepare materials for them.

2 – A new integrated science project should develop its own teacher preparation materials using an approach similar to that used by FUSE (Ohio State University) or Unit Package Approaches.

3 – The teacher training materials for any one country should be developed by those who are directly concerned with the training.

4 – Materials previously listed for a specific country, for example those of STEP at the secondary level and CCSP at the primary level in the U.K., might be modified for use in other countries, and provide a stimulus to the production of local material.

5 – All teachers and supervisors of science in a given school or area should be involved in any in-service teacher training program. This will facilitate a smooth transition toward the teaching of integrated science.

6 – There should be continuous modification of all teacher training programs, based on evaluation and feedback.

DISCUSSION AND COMMENT AT PLENARY SESSIONS RELATING TO PRE-SERVICE AND IN-SERVICE TRAINING OF TEACHERS FOR INTEGRATED SCIENCE

The plenary lectures on pre-service and in-service training were considered by different speakers, and different working groups discussed these issues. Everyone, however, was aware that neither could be considered in isolation and that a new entrant to the teaching profession, no matter how well trained, would be unable to put his ideas into practice if the school and the science department which he joined were unsympathetic and lacked the understanding and the materials necessary for him to practise the methods which he had learned at college. But changes in the science department could be facilitated by an influx of young teachers who were knowledgeable about the latest ideas, methods and resources relating to school science. An interplay of pre-service and in-service training of teachers of integrated science was called for. Experienced teachers could help with initial training and lecturers in colleges of education need to maintain a close working relationship with teachers in neighbouring schools, not only in connection with teaching practice but also as partners in developing and introducing new courses. Inspectors and administrators need to be participants in innovation and not mere critics. An inspector who makes no contact with the ideas developed in initial training is unlikely to support the new teacher in his struggle for mastery of integrated science and all the problems of controlling today's classes.

Teacher training is no longer the sole prerogative of colleges of education, inspectors and universities. H. Thier asked that every teacher be deeply involved in all aspects of training. Senior teachers will make many decisions about methods and content but it is when every single teacher feels involved in and committed to the process of innovation that progress will be most effective. The best ideas can be converted into pedestrian practice by a teacher who fails to see their true value or lacks the drive to put them into practice in the way the exponents of the ideas envisage. Yet when demands are made upon teachers and their willing co-operation is obtained, it is rare for them to fail to respond. J. Spice pointed out that teachers working together can learn much. Many teachers fear that they do not have the knowledge to tackle unfamiliar material. This is especially true at the upper secondary stages and above and it is necessary to provide the knowledge and to give confidence in its application. At the stage of course construction and formative evaluation, teachers of different sciences can inform and inspire each other as discussion proceeds and when the course is implemented it may be possible for two different specialists to work together for at least a year before each attempts to present an integrated science course on his own. In this way the physicist can learn from the chemist and the chemist from the physicist, training each other for the time when they can each carry the whole of a relatively advanced integrated course. Despite the fears of many teachers this procedure proved possible in the trials of the Nuffield Physical Science Project. It was possible to have two sixth form teachers with one class for a limited period of time, and the experience each had proved to be invaluable.

S. Haggis regretted than in-service training of teachers has so far taken place mainly outside the school. She felt that there should be more emphasis on in-service training within the school. The physics, chemistry and biology 'specialists' in a particular school should work together and teachers of all subjects in the curriculum could pay attention to increasing the unification of the school's programme as a whole. R. Meyer approved such an arrangement but noted that educational discussion of fundamental issues does not arise spontaneously. He would like to see curriculum consultants in schools associated perhaps with media centres. The consultants would link with the developers of curriculum projects and with lecturers in colleges of education and universities. In their schools they would stimulate discussion and help with the production of support materials for teachers breaking new ground. Advice and aid which is critical yet of practical use is needed by any innovator. The science teachers need advice on the choice and execution of experiments and demonstrations, as well as with the content of the course and its theoretical presentation. A media centre in school can help with a wide range of audio-visual materials such as tape-slide programmes, overhead projector transparencies, assignment cards, or self-instructional programmes of one kind and another. The curriculum consultant could have access to new apparatus, either in consultation with the in-service and pre-service training establishments or by direct liaison with laboratory suppliers.

The variety of forces acting upon teachers was noted by several contributors. Many of the forces are negative and tend towards conservatism and the maintenance of the status quo. Inspectors, advisers, head teachers, other administrators and even parents are often unsympathetic towards a teacher struggling to make changes and to try courses with which he and they are unfamiliar. It is essential that all these partners in the educational enterprise be pulling in the same direction and this can only be achieved if they are informed about what the school is trying to do and involved in some way in the changes which are taking place. V. Parsegian drew attention to the difficulty with unsympathetic science colleagues. Obstruction by one or two members of school faculty can cause many problems. In some cases the most extreme objectors are best ignored and allowed to go their own way untroubled, for a teacher who approaches his teaching with an unwilling, destructively critical attitude is likely to do harm to the changes he is purporting to introduce and worse still, might do harm to the children he is claiming to educate. The attitude of professional societies of scientists can also facilitate or hinder changes. Professional societies can do much to help integrated science teachers through their education groups and also by indicating to the less sympathetic societies the merits of acknowledging their inter-dependence. An enlightened attitude on the part of the scientific societies could contribute substantially towards the climate of opinion in the schools and in the scientific community as a whole.

Mrs. Haggis had said in her talk: "Society thinks of the teacher as the person who has all the answers". L. Elton believed that teachers expect this of themselves too. One of our most important tasks is to increase teachers' self-confidence and this is very difficult if a teacher believes he must know all the answers. If it is true that what teachers really want to do is to teach, not learn, and that they are reluctant to contribute to and experiment with methods of teaching and educational practice, then these attitudes must be taken into account in any training programme. Most teachers do not want to make fools of themselves in front of others. How peculiar is this to science teachers? Do English teachers worry if they cannot explain a poem as science teachers worry if they cannot solve a problem? If science teachers are peculiar in their expectations of themselves, to what extent is this due to the nature of the subject and to what extent is it due to the way they themselves have been taught? In particular, does the teaching of science in universities and other tertiary institutions give confidence to face the unfamiliar, or destory it? If the latter, then those of us teaching in tertiary education, training teachers or not, need to think very seriously about our courses and our methods.

Teachers of children in the elementary grades (5 – 12 years old) are more used to tackling a broad range of subjects than are secondary and tertiary teachers. Most of them are, however, untrained in science. Some will have rejected physics, chemistry and biology whilst still at school, finding them dull or difficult. Others will have found other areas of study more rewarding without actively rejecting all science subjects. In any event there is not much science as we understand it today in the elementary schools (even 'Nature Study' has often been taught unscientifically, by rote). The introduction of any contemporary science teaching scheme into a school will almost certainly demand a re-orientation with regard to content, approach and practice. H. Thier asked whether we are not asking far too much of the average elementary school teacher. Is it realistic to ask a teacher to change her whole approach to the class whilst coping with quite new materials? To ask a teacher to learn new subject matter and at the same time to develop for herself appropriate experiments, assignment cards, methods of recording and reporting, methods of arranging the classroom and so on, is unrealistic. It is more productive in the long term to provide materials and advice to enable her to get started. Then she can grow from success and positive accomplishment to independence. One of the aims of a training programme should be to enable a teacher to tackle the material provided in a critical, progressive way, with a view to adapting it to her own circumstances, children, finances, classroom space, climate, etc.

The question of how best to help students and practising teachers was frequently raised. Nobody could offer definitive solutions and the style of curriculum development, innovation and training varied considerably both between and within countries. W. Hall distinguished curriculum development and materials development. He quoted the Nuffield Junior Science Project as an example of excellent curriculum development which influenced some of the best teachers but failed really to take root. The support materials fell short of the needs of the majority of English primary school teachers who found the ideas difficult to implement. It did, however, provide a basis of thinking and example which enabled the more specific materials of the Science 5–13 Project to be accepted and applied in a productive way. A common approach to integrated science teaching, especially at the elementary level, is via units. These have been developed for such projects as the Elementary Science Study, the African Primary Science Program, The Australian Science Education Project and many others.* [1] They cover in some detail certain areas of study and offer useful instruction in content of science being taught and also advice about how to use it with children. In a school where everyone from children, through parents, teachers, head teachers and administrators, all understand that the use of the units will involve activity, experiment, perhaps more noise than usual and a certain amount of untidiness in the classroom, introducing such units is comparatively easy. However, these circumstances do not always pertain and although foundations have generously supported the preparation of materials and teachers' guides, they have seldom funded the study of effective implementation of the materials in a wide range of schools. Neither have they supported research into the processes involved. A conspicuous exception is the Science Teacher Education Project which set out *inter alia* to provide resources for the training of teachers rather than the education of children.

Several speakers including P. Thomsen doubted the value of exhortation in print. It is highly unlikely that teaching styles can be changed merely by giving teachers guides which extol the virtues of discovery methods. In the same way use of the lecture method to advocate experiment and discovery lacks both logic and conviction. If we believe that children and students should find things out for themselves from experience, then it is clear that teachers too must tackle unfamiliar material in a context where uncertainty exists and decisions must be made. Teachers need to be convinced personally and this can be done either by example or by discussion where a reasoned case is made for the new proposals. In this whole area course organisers have few hard facts with which to work. Research results giving concrete practical information about the outcomes of various procedures are few and far between. Just how should we go about organising the retraining of teachers for integrated science? Should teachers tackle work intended for children? Should more sophisticated 'discovery' experiences be available? Is it enough for teachers to skim 'discovery' materials or should they work them to the limit? Should they aim for depth, for accuracy, for precision? Should they be called upon to report their findings? As a child would? As an adult would? Which issues when presented to teachers stimulate the most vigorous, productive discussion? What experiences are counter-productive? These questions cannot be answered with certainty. They will vary from community to community. Teachers deeply conditioned to accept their own superiority over children will need different treatment from those accustomed to exploring with the children. Organisers themselves will have to adopt 'discovery' approaches to teacher training.

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*A list of integrated science projects (with addresses) is included in 'New Trends in Integrated Science Teaching, Vol. 2', UNESCO 1973.

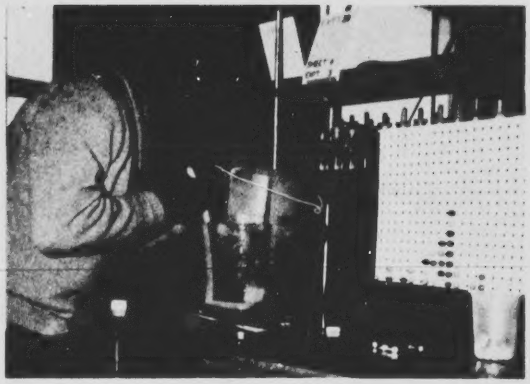
At this time there exist very many integrated science schemes. It is uneconomic, probably unnecessary, for anyone contemplating the introduction of integrated science to start from scratch. There is so much from which he can select, on which he can build. But as W. Hall pointed out, it is not the job of project leaders to act as travelling salesmen offering a package deal. J. M. Gutierrez-Vazquez stressed that local problems must be solved by local people using local resources and local materials. For developers to choose wisely among the materials available to them they must know what is available whilst taking into account their own people's facilities and abilities. The final choices must always be made in the light of experiences with other teachers and children in the schools. New syllabuses, text books, teachers' guides, experiment books and question books may all be needed. Some contributors, notably L. Elton, felt that a range of teaching methods and aids, based on educational technology was essential and that all teachers should understand their importance. Others felt that educational technology was of secondary importance and could even lead to the student doing fewer experiments and taking less personal responsibility for his own learning.

N. A. Ayodele Cole was concerned about differences between elementary and secondary teachers and their differing needs. Africa is well served with elementary science schemes of an integrated nature developed by African scientists and educationalists in collaboration with counterparts from North America and Europe. They have found it possible to use local materials and to adapt them to local ways. At the secondary level there is less consensus between countries and integrated science is less common. Co-ordinated work similar to that at the elementary level could provide high quality material adaptable to different regions of Africa. A. Torrie felt a dichotomy between the training of primary and secondary teachers and looked forward to a time when teachers being trained for any school would be trained in the same institution. A gulf between elementary and secondary aims and methods is as serious as a gulf between science subjects.

Throughout the discussions it was stressed that teachers, teacher trainers and administrators must work together if integrated science is to become an effective instrument of education for the majority of our children.

Part 3

The Improvement and Evaluation of Teacher Education Programmes for Integrated Science



Left: Open University Students taking science based courses conduct experiments at home using a standard experiment kit.
(Photo: Open University)

Above: Finding the distribution of the volume of air held in the lungs of a group of teachers.
(Photo: Graham Pollock)

Right: Teachers of integrated science need extended knowledge. Books, radio & TV can help.
(Photo: Open University)

Below: In-service education in Sarawak.
(Photo: Derek Carter)

Plate 3: Teacher Training for Integrated Science

INTEGRATED SCIENCE, TEACHER EDUCATION AND THE IMPROVEMENT OF SCHOOLING

John I. Goodlad.
University of California, Los Angeles

Let me begin by noting a bias, growing almost inevitably out of the fact that I have spent the first half of my life to date in Canada and the second in the United States. There is no point in apologizing for my Western view. Few of us escape parochialism and a perspective falling far short of embracing the whole of mankind. But this need not block the realization that we need a universal perspective more urgently now than ever before. It is a theme of this conference that education – and especially schools – must do better in freeing subsequent generations from the limiting influences of their time and place. I hope, then, in spite of the admitted bias, to transcend the immediacy of my time and place sufficiently to say at least a few things with which all of us can identify.

TOWARD CLARITY OF ENDS AND HUMANIZATION OF NEEDS

By now in this conference, presumably, we have transcended its theme, 'Education of Teachers for Integrated Science'. For, if we focus *only* on fusion of several disciplines commonly viewed as discreet into some more unified curriculum frame and are pre-occupied primarily with preparing teachers for such an arrangement, then, even if we are successful, the consequences are likely to be negligible. Neither this nor any subsequent generation of students will rise above self and immediate interests as a result of such manipulations. We must be concerned, rather, with assisting students to become useful members of society, viewing some measure of scientific literacy as one means towards such an end. Turning that thought around, we are concerned with humanizing man's knowledge so as to render it easily and productively accessible to all citizens.

Integrated science is no panacea. Both separate subject and so-called integrated curricula can be defended and go in and out of favor, not because one is proved better than another but because fashions change. Change, by definition, is a movement from one thing to another which is not necessarily new or better. We need not go back far in the history of schooling in the United States to find successive waves of at least the rhetoric for changing fashions in curriculum organization. I doubt, however, that a student's participation in one curriculum arrangement rather than another will make much difference to attainment of the larger goals of education held by the planners of this conference.

Let us move, then, from the matter of preparing teachers for integrated science to the stated aim of this conference: '. . . to study in depth the education of teachers, both initial and in-service, to teach science in integrated and co-ordinated ways and to relate science teaching to the needs of modern society'. There is potential here for carrying our dialogue to the whole of schooling: what is to be included in the curriculum, how the school is to be organized, the persons who teach there and the ends toward which the whole is to be directed. And if the whole of schooling is humanized – that is, made appropriately ready for those who are to partake of it – then schools just might make a difference.

There has been doubt in some quarters as to whether success in school, as traditionally interpreted, makes any difference in regard to ends that really matter. To quote my colleague, C. Robert Pace:

> "Academic grades predict academic grades, and scholastic aptitude tests predict scholastic performance. But neither has much relationship to anything else –

> not creativity, not inventiveness, not leadership, not good citizenship, not compassion, not esthetic sensitivity, not expressive talent in any of the performing arts, not personal and social maturity, not mental health, not vocational success, not family happiness, not honest workmanship". [1]

In recent years, this doubt has grown to what Robert M. Hutchins calls 'the great anti-school campaign', and I quote him: '. . . nobody has a kind word for the institution that was only the other day the foundation of our freedom, the guarantee of our future, the cause of our prosperity and power, the bastion of our security, the bright and shining beacon that was the source of our enlightenment, the public school'. [2] The critics make strange bedfellows, ranging from those who think schools pamper the young, to those who think they are impotent, to those who view schools as powerfully inhumane. They probably are or do none of these things, or at least not to the degree claimed by the critics. Our schools were never as good as our nostalgia leads us to think they once were; nor are they as bad as we now, somewhat masochistically, like to depict them. They were, in the past, largely a reflection of a young nation's confidence in the future. They are today, in large measure, a reflection of a nation grown older, having to substitute for somewhat simplistic notions of 'upward and onward' something infinitely more complex called maturity.

It must be a cause of great dismay for nations with only partially developed school systems to view the uncertainty with which a few developed nations regard their schools. Perhaps they fear, 'There in a few short decades go we'. But the future lies not in abandoning the drive for universal access to schools but, first, in adjusting our expectations for them. To quote Hutchins again:

> "The limitations within which our education system operates are severe. It is a means of accenuating and perpetuating accepted values, not of raising a nation by its own bootstrap into a different and better world. This is true of any system of education under any form of government". [3]

Physical restraints alone should give us some pause in regard to our expectations. By age 13, a child has spent, at best, only some 7560 hours in school out of the approximately 114,000 hours he has lived. This works out to about 6.6% of his life to date spent in school – and little or none of this during the presumably most formative early years. The addition of 5 years to include completion of high school raises the fraction of total life time spent in school by the age of 18 to only 8.2%. It is doubtful that this figure is higher than 9.0% for any country and, of course, when we add secondary school, we are talking about only a fraction of the age group. It is estimated that, in the United States, the portion of an 18-year-old's life to date spent viewing television is approximately 9.0% – and a large fraction of this viewing was before the age of 6.

It becomes glaringly apparent that when we talk about what ails schools, we are examining in microcosmic fashion what ails a nation and a people. It is clear that the schools should shoulder no more than a small fraction of the blame and should be held neither responsible nor accountable for remedying the whole. Furthermore, social engineering – not education – is the more likely answer to overpopulation, hunger, joblessness, and human misery. While elementary education appears to be a good economic investment, the most educated in the United States currently appear to be the least employable. And the fact that elementary education increases the GNP is because primary schooling contributes to literacy more than to immediately marketable skills. Although it is true that those countries with the most advanced technology also have the most developed educational systems, it does not follow that there is a correspondingly greater demand for technical training or courses in science in their universities. In fact, it is in the social sciences, particularly those related to social and environmental welfare, and some of the humanities that enrollments tend to increase.

The schools are blamed too often for failing where they should not even be trying. They are blamed, for example, for failing to provide job training – and even for failing to create jobs! Industry is well-equipped to undertake such training – and might be encouraged through a form of tax rebates to provide it. Industry is not well-equipped, however, to provide for the integrative reflection so central to the education process and the proper function of schools.

The schools are blamed, also, for failing to respond to exhortations to serve community interests. It is the community which has the resources to provide orientations to or internships in community life, but the community is ill-equipped to open up alternative modes of life or the wonders of a larger world. For these, children and youth require the basic tools for learning.

No, if the schools are failing, it is in other realms: in the general failure to define what might best be done in 6 or 7 or 8% of a young person's life, and in the school's failure to use this little time that is available vigorously and creatively to do what no other institution can do. To use the language of this conference, the schools have neither an integrated sense of purpose which those running them have internalized nor a parsimonious integration of means. To quote Hutchins once more, the school 'is the only institution erected by the society for the specific purpose of helping the citizen learn to live in it and . . . of helping him learn how it may be improved'. [4]

We are saying, then, that a central purpose of the schools is preparation for citizenship – intelligent citizenship. It would be presumptuous of me to suggest how individual nations might specify the requirements of citizenship. But it is significant to point out that few countries omit from statements of general aims for their educational systems the importance of understanding other countries and, in fact, the world community. It is significant, also, to point out that world-wide conferences on mankind problems – pollution, population, poverty, and the conservation of natural resources – are now commonplace. While all countries are pre-occupied in varying degrees with schools as an economic investment and as sorting mechanisms, most are concerned increasingly with the provision of *permanent* literacy and the development of a national pride not entirely divorced from some more universal perspective.

An examination of the stated educational aims for most countries reveals considerable uniformity: teaching the basic tools of reading, writing, speaking, listening and figuring; providing some understanding of the cultural (national and regional) heritage; understanding other peoples; understanding the natural or physical world, including man's adaptation to and utilization of it; and gaining some proficiency in higher literacy skills of critical judgment and constructive group participation. What the political and educational leadership of many countries despairs of, however, is the gap between these high-sounding aims and the day-to-day conduct of schooling. If there is any one thing for which the schools should be seriously faulted, it is the sameness of the daily fare, the relatively passive and uninspired maintenance rather than creative molding of the school environment. For this – and not the failure of the schools to reform society – those who run the schools are responsible and must be held accountable. Whether the schools do a little worse or a little better than average in those few things that are readily measured by standardized achievement tests is of far less importance than whether or not a school has a clear sense of mission and a commitment to get on with it.

THE LIMITATIONS OF CURRICULUM REFORM

Likewise, whether or not we plan integrated curricula for the school makes little difference in regard to whether schools vigorously pursue significant ends, such a relating science teaching to the needs of modern society. This was the realization that dawned rather rapidly on David Chen soon after he became director of the Elementary School Science Project (MATAL) at Tel-Aviv University. The Project was designed from the outset to update science teaching in the lower schools. Under Dr. Chen's direction, it soon moved into an array of teaching problems and the complexities of effecting curricular change in schools. I am sure that other illustrations of the frustrations faced by curriculum reformers readily could be identified, but MATAL serves nicely to illustrate a major thrust of my argument.

Although responsibility for the schools in Israel is centralized in the Ministry of Education and Culture, there is a tradition of considerable local responsibility. If one were to place a large number of countries on a continuum of centralization/decentralization of authority and responsibility for schooling, I believe that Israel would fall in the middle range – not as centralized as Korea, for example, and certainly not as decentralized as England. Therefore, it should be fairly easy for most countries to identify with MATAL from the viewpoint of relevance and feasibility of replication.

At this time, MATAL has a relatively fully developed curriculum for kindergarten and the first few grades. The approach is thoroughly integrated, weaving in concepts from mathematics and all the sciences as well as teaching processes drawn from studies of child development and learning. It would be difficult to fault the project on validity of content. And, although questions have been raised about its appropriateness for young children, experience to date blunts such criticism. However, one of the requisites of the program – that children work together with the materials in small groups – runs counter to the so-called 'frontal' pattern of teaching so common in Israel and many other countries.

It became clear to Dr. Chen early in the project that much of the force and substance of the educational process he was seeking to develop would be lost in the passage of the materials from development to implementation. Much recent experience with curriculum reform in the United States bears out this concern. [5] As a biophysicist coming new to the curriculum of the primary schools, however, he was only intuitively aware of the forces to be contended with if MATAL was to become something more than attractive packages of materials. *He realized that he had to deal with the culture of the school.* If real change was to occur, then, MATAL had to become part of that culture. In effect, he became pre-occupied not merely with the integration of scientific and mathematical concepts in a new curriculum project but also with integrating the changes in teacher style and behaviour required by MATAL into the social system of the school. In the process, the social system itself would have to change.

BLOCKS TO SCHOOL IMPROVEMENT

The problems faced by Dr. Chen and MATAL are not unique. Many universities have developed curriculum packages based on new interpretation of the teacher's role. They assume that if the materials are adopted, the teacher, and therefore the school, will somehow miraculously change. Unfortunately, this is not the case. Schools and teachers go on doing what they have always done and, sooner or later, the new ideas of the curriculum planners are abandoned or even never discovered at all.

Hutchins has said, 'The unique function of educational institutions, if any function exists, and if we can discern what it is, is likely to be so complicated and so time consuming as to require the full attention of those who are responsible for them'. [6] He may be getting close here to why so many schools are conducted aimlessly, covering in rote fashion what is prescribed in textbooks and syllabi masquerading as curricula. In no more than a handful of schools is there a 'critical mass' of responsible parties – principles, teachers, parents, children – seriously engaged in determining mission, constructing alternative modes of proceeding with this mission and appraising the consequences; in effect, giving their full attention to improving the school as a social institution. [7]

I realize full well that the degrees of freedom for engaging in such activity vary widely from country to country and that school people in centralized systems will claim they have little or no flexibility. I maintain, nonetheless, that more freedom than is claimed (and certainly used!) exists almost everywhere and, further, that commitment of a nucleus of persons to total school improvement in each school is absolutely essential to institutional vitality.

Two pre-occupations, more than state or national restraints, great as these usually are, inhibit the vitality of schools. One is pre-occupation with immediate end product in the way a factory is pre-occupied with the production of goods. We wring our hands over low reading achievement, frequently putting the stigma of failure on the pupil as though it were his fault or that something positive would result from such blindly inhuman and irrational behaviour. At best, we put in a new system of teaching reading, usually with all the textbooks and accompanying paraphernalia, though it is a fact that no more than 5% of the deviance in reading scores can be attributed to this or that reading method. To teach children to read, we must take this mission seriously, approaching it from every possible vantage point, noting the difficulties and devising remedies for them – in effect, by swarming all over the problem. The problem with the measurement syndrome is that we learn only that the horse ran a slow race; we fail to learn whether he carried a heavy load, was not fully rested from an earlier race or was jostled on the track. And so we do not know where or how to intervene for improvement.

The second pre-occupation is with our specializations. We are mathematicians or physicists or even specialists in integrated science – but not educators. The goals of many educational systems are stated within the context of the subject fields. Most high schools are organized into departments: foreign languages, the native language, history, mathematics, chemistry, and the like. We add grade levels and then classes to these subject matter divisions, and the result is a lot of little cells, connected to little or no reality beyond themselves and certainly not productive of something greater that might be considered an education. In some secondary schools, the compartmentalization is such that teachers meet only by departments and often levels within departments. Meanwhile, chain-link fences go up around the schools. Are they to keep the students in or out?

The problem of specialization grows out of the teacher's preparation in college or university. In the United States, much of higher education is devoted to preparation for something else – entry into graduate studies, meeting the requirements of the American Chemical Society or fulfilling specifications for a teaching credential. Except for a few noteworthy efforts to the contrary, so-called general education is more a collection of introductions to specializations than a cohesive, planned effort to achieve a few central goals of education held in common by the faculty and understood by the student body. Recently, a young lady with a fresh but not very shiny B.A. degree came to me to talk about teaching as a career. Her major in political science prepared her for nothing, she said. I asked whether it might have prepared her to participate more intelligently in the political affairs of her community and the nation, but apparently, she had not thought before about the question that should have been before her all along. My guess is that her attention had been directed primarily to the requirements for each of her courses and to nothing beyond. Should she, or the institution, or both be faulted?

It is because higher education is so badly splintered and the lower schools, in turn, so instrumental to subsequent levels in the system – whether or not many of the students go on through it – that I often despair of significantly changing the pre-service education of teachers so that they will transcend their specialization sufficiently to become educators. However, by teachers fashioning their schools into centers of inquiry about the educational process for themselves and about significant issues for their students, it may be possible to redirect the education of teachers, both pre-service and in-service.

A word about the common conduct of the in-service education of teachers is in order. Traditionally, it has focused on the individual teacher, not the school. In the United States, teachers receive credits for salary increases by attending district-wide institutes on some aspect of the teaching process. The themes tend to be too general and neither theoretically nor immediately practical. In addition, large numbers of teachers attend evening and summer classes at universities, receiving credit for advanced degrees. Frequently, they take courses in school administration and are rewarded on the salary schedule, no matter how irrelevant to their duties the courses and the resulting degree may be. Supervisors view their in-service responsibility as being to classes, and teachers soon become overwhelmed with the magnitude of their task which is, indeed, overwhelming when thought of in these terms.

In a study of 67 elementary schools in the United States, my colleagues and I found the foregoing to be a quite accurate description of teachers' and supervisors' in-service educational activity. [8] We found that rather than turning the attention of teachers and supervisors to the problems of the school as a whole, existing in-service education programs turned their attention elsewhere, taking the teachers away from their schools, and, therefore, away from questions of school function, climate, curricula, effectiveness, and the like. Only 4 of the 67 schools appeared to us to have a nucleus of concerned and responsible persons committing their attention to the institutions as a whole. And these 4 schools proved to be among the best in our sample.

To repeat, part of the school's impotence grows out of the limited time and resources available to it. But providing it with more time is not the answer, since it does not now use well the time it has. Rather, before concluding that the school, like the horse, should be eliminated for running a poor race, those in it should turn their full attention to assuring that it does a few things well. The school as a social institution – and especially its adult social system [9] – moves to the center of the stage in our search for school improvement. As David Chen insightfully realized, if one is to become seriously and productively engaged in seeking to change any part of the school's program, he must become involved with the school as a functioning social system. He based his strategy on principles discovered in a five-year effort I directed to modify the adult social system in a consortium of schools and to study the attendant problems.

TOWARD RESPONSIVE SCHOOLS

The project grew out of my observations, over a period of years, of the reactions of visitors to the University Elementary School, a laboratory elementary school at UCLA where many of the most strongly supported recommendations for school reform were being implemented. It soon became evident that visitors who wanted to implement these changes in their own schools felt impotent to do so for a variety of reasons, most of which appeared to relate to the climate or context of their own schools. Each school has a culture of its own, a culture that has adapted itself to survival within the restraints of the larger societal context. Somewhat ironically, very little is known about this culture, [10] in spite of all the attention and criticism directed to it. Consequently, very little is known about how to change it. Teachers focus on the children they teach and their classrooms. Their associations with colleagues tend to be impersonal, superficial, and non-intellectual.

It is a sociological and biological principle that anything *significant* injected into a system will have repercussions throughout the system, taxing its powers of rejection or assimilation. What many teachers desire, especially when they catch a glimpse of other teachers meaningfully and productively at work as educators, is to participate in a school culture that provides good-work – good human work – not just a job. My own association with dozens of school faculties – 'ordinary' school faculties, if I may use such a barbaric word in referring to people – supports my confidence in this observation. And so, the most insightful visitors to an exciting school go away not just with the desire to tack on an innovation in their schools but to engage in dialogue with colleagues about how to improve the culture of their own school. Back home, however, confined to the isolation of their classrooms and disciplines, knowing not how to proceed on a broader front, they feel frustrated and impotent.

The project which my colleagues and I launched in 1966 was based on the premise that the individual school is the key unit for educational improvement; that there is in every school at least a small nucleus of persons seeking worthwhile work and the satisfaction that comes with it; that the principal is or can be a significant force for change; that schools are enormously impervious to changes imposed from without, effectively rejecting, isolating or modifying such changes so that they pass through the system like a mild cathartic; that focusing internally on the institution rather than looking outside for some innovation of near-magical power is the more promising route for productive faculty activity; that the prestigious external referrents for legitimatizing the effort to change are exceedingly helpful; and that association with external peer groups committed to similar tasks of self-improvement likewise legitimatizes and enhances the process. Following these premises, we brought together 18 schools in 18 separate school districts, in what became known as the League of Co-operating Schools [11]. The purpose of the school personnel in the League was to improve their own schools; our purpose was to study educational change. It proved to be a mutually satisfactory and satisfying relationship.

Following our premises, we encouraged in each school a process of dialogue, decisions, actions, and evaluation (DDAE) developed and refined by principals and teachers, which became the standard procedure for both the entire faculty and small groups. The process of DDAE, as developed in the schools, forced attention not only to the problems of the schools but also to systematic processes for dealing with these problems. The staff was required to define the problem, go to the literature and other resources for help, and then to translate findings into strategies for action and subsequent evaluation of their effectiveness. Faculty meetings were not to be simply the 'good fellowship' approach so characteristic of school faculty meetings, when they occur at all.

Increasingly, these discussions drew in a larger array of responsible parties from the school district and the community. Principals, usually bringing along several teachers, met monthly to discuss together their leadership roles, a process that proved to be exceedingly difficult and demanding. Our staff refrained from playing the expert consultant role, encouraging the growing strength of the adult social system in each school and building the League as a larger social system legitimatizing ideas and supporting the activities of the schools comprising its membership. As school staffs matured in their confidence and expertise, they increasingly sought to exchange ideas with others in the League through a newsletter and frequent workshops designed to teach each other. Increasingly, they extended these activities outside the League schools and a 'ripple effect' began to take place.

We were not at any time advocates of specific reforms or innovations although our preferences and predilections undoubtedly showed through and we made no effort to hide them. We were acutely aware of the danger of school staffs becoming narcissistic in their pre-occupation, but the League structure soon dispelled our fears. Criteria for looking outside themselves – and especially to the relevant literature – were built into the process of DDAE. The teachers and we were deeply concerned about the schools becoming responsive to the world around them [12]. Perhaps this is why many of them are so interested in one of our new projects, designed to explore how the idea of mankind might be brought into the elementary school curriculum.

It was this part of our work that so intrigued David Chen in regard to MATAL. His staff encompassed the complex problems involved in creating an integrated elementary-school science curriculum exceedingly well, I must say. But their concerns and expertise did not encompass the full range of problems inherent in moving the MATAL materials and accompanying pedagogy into the schools of Israel. It was here that he perceived a possible marriage between the concepts underlying our project and those guiding MATAL.

To go into detail regarding the findings and impressions from our 5-year study of educational change and the League of Co-operating Schools would be to go beyond the purposes of this paper and the conference. They are reported in a series of documentary films [13] and several books soon to be published [14]. But a few observations are relevant. First, there is no question that most of the teachers involved were 'turned on' by the process. Many said that they had never worked harder, had never before felt as exhilarated about what they were doing and would never go back to former modes of operation. Second, there is no doubt that they concerned themselves with significant questions of educational ends and means. Our data are replete with illustrations of truly substantive dialogue. Third, there is ample support for the proposition that involved, enthusiastic teachers arouse the support and participation of parents. Since schools absorb such a small fraction of the student's young life, the benefits of school and home working together for significant educational goals are obvious. Fourth, the kinds of changes that have been so much recommended in recent years – individualized instruction, the adoption of revised curricula, nongrading, team teaching, etc. – were introduced in most of the school with little fanfare. These simply proved to be rather natural responses to the ongoing search for better ways. Successful adoption and adaptation of an innovation in one school led to early communication with other schools and rather rapid implementation throughout the schools comprising the social system of the League [15]. Fifth, even casual observation reveals that the spirit of involvement and commitment carried over to the children, especially at the primary level (K–3) where the kind and intensity of student activity was impressive. This was less the case at upper elementary school levels where the sterility of textbooks, workbooks and the curriculum in general appears to have a deadening effect that is extraordinarily difficult to overcome. Sixth, on measures of attitude toward school, boys and girls in League schools responded more positively than pupils in control schools.

Always, I am asked the question, 'Yes, but how did the students do on achievement tests?' The answer is that we do not know and did not attempt to find out. There were two reasons for the latter. First, we did not have the resources to find out with satisfactory precision, even had we wanted to. Second, and more important, we wished to emphasize the fact that the focus of attention was the school, not the pupil. It was our assumption that the creation of more humane, intellectual, problem-solving environments for and by the teachers *ultimately*, though perhaps not immediately, will have a beneficial effect on the lives of the students in them. These effects probably will not be reflected early, if at all, in achievement test scores – but they will show up, we believe, in relations among students, in their compassion, in their compassion, in their sensitivity and, yes in their citizenship behaviour.

These things, too, can be measured to some degree, but they do not ordinarily appear in batteries of achievement tests. We are not at all sure that the start in these directions we believe the children to have received will show up on any conventional evaluation device. A ship that changes its direction only a few degrees is visibly on course for some distance afterward but, obviously, given enough time, will reach a quite different destination.

There are those critics who say, nonetheless, that I am begging the question, which is, 'Did these children learn more?' That is, indeed a good question and one with which teachers might begin a substantive dialogue. Soon it should lead to a more important one, 'What *should* they be learning?' I am convinced that once teachers come to grips with such a question and then move in disciplined fashion through the process of DDAE, they will improve the institutions for which they are responsible. At present, however, whenever I am told that the children in a given situation did badly on whatever a given achievement test measured, I am given no directions as to what should be done about it. Or, I am told that the schools should be abolished or that nothing but custodial functions can be expected from the schools. Neither alternative is good enough. The schools can become effective, as those who have had the experience of making one so can testify.

IN CONCLUSION

Now, I return to where I began. Neither the separate science disciplines nor integrated science is sufficient to make our schools more powerful educationally. Nonetheless, I do not wish to suggest for a moment that what is taught and how it is brought together for effective learning are unimportant. The curriculum is one of the major factors of schooling, demanding the most rigorous scrutiny. Unfortunately, most of the tasks of revision lie outside the time and capabilities of most of school faculties.

I am not at all sure that the current zest for integrated science, social science, or humanities is equally beneficial for all phases of schooling. It seems eminently reasonable that the very young should be introduced to concepts such as size, weight, shape, and relativity quite apart from what would be for them the burdensome structure of each discipline. It seems equally reasonable that children of an older age should arrive at physical and ecological principles through the study of machines and ponds. But it may be that science in a subsequent phase of schooling can be approached effectively through a single discipline, ever mindful of the relevance of its methods and concepts to the physical world in which the students live. It seems equally reasonable that, during the course of a general education, students should grapple with all patterns of curriculum organization for which strong cases have been made during periods of recurring fashions. It is important that we create alternatives, all scientifically valid, to which schools can reach out in seeking to provide vital fare for their students.

But these alternatives, however well thought out, will not suffice to improve the schools significantly. We must be thoroughly realistic in facing the fact that very little of the substance of reform will find its way into the schools unless there are in them adult groups seriously engaged in determining the mission of their institutions and in looking outside for better ways to fulfill this mission. Since this condition is sorely lacking in the schools and is, I believe, the main reason for their impotence, it follows that most curriculum building activity, whether or not approached with a view to integration of the subject fields, amounts to little more than wheel-spinning.

The implications of this conclusion are sobering, indeed, for those who would change the schools through curriculum planning. There may come a day when the schools are so responsive to curricular alternatives that curriculum makers need only concern themselves with various patterns of subject matter organization and the preparation of multi-media packages of materials. But such a day will not come soon or easily. Therefore, curriculum planners, in the spirit of the little group making up MATAL and a handful of like-minded groups around the world must join with those parties seeking to rethink the mission, functions and activities of the institutions for which they are responsible. It will be difficult, challenging work – good work for educators, after all. And who ever promised us a rose garden?

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THE EVALUATION OF PROGRAMS FOR THE EDUCATION OF TEACHERS OF INTEGRATED SCIENCE

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I have been a teacher of one kind or another for many years and I have seen some words become very popular, words like curriculum developer, innovator, structured, unstructured, process and many more. Let me make it quite clear; I am not a professional evaluator, I am merely someone very interested in developing programs for the improvement of science teaching. But I wish to discover rational ways in which we can take decisions. Evaluation will help us to do this.

During the past decade a series of attempts have been made at introducing new curricula, adapting them, writing texts, producing equipment, writing materials and training teachers in pre-service and in-service courses. The time has now come for us to evaluate what has been done, in order to improve our efforts and to make them more productive.

It is always nice to look at beautiful diagrams, flow charts and systems, to see how everything fits together in a logical way. But things don't happen like that in our country where it is very difficult to have things so well organised, so nicely put together, because things just don't seem to work out that way. And I suspect that the same is true of many countries. My problem, and perhaps yours too, is to produce a good evaluation program for our conditions and to decide how best to spend time, money and energy in developing integrated science courses and how best to train teachers who can use them in the schools.

Before starting to discuss *how* to evaluate I would like to discuss what aspects of a teachers' program we *should* evaluate. We expect teachers to do many things. They are expected to construct their curriculum, to make decisions about the content of their courses, to produce certain attitudes in the students, to organise all kinds of outside activities. They have to go on courses. They have to adjust to the educational system and yet assume an innovative role. The two roles can be in conflict: adjust too much and a teacher can lose some of his drive and imagination. It is already clear after only two days of this meeting that we ourselves cannot do all the things we expect the teachers to do. We expect so much: they have to go to the classroom, to teach the children and to handle not just the little things we do but the real classroom situation together very often with the principal, the supervisor, the inspector and all the other representatives of educational services.

Anyone interested in evaluation, no matter where in the world he is working, must face the issue of the complexity of the teacher's role. He may decide to make a set of objectives (so popular just now) or he can decide to approach his task via models, perhaps an accountability model, or a competency list and to use one or more of these as a basis for his evaluation. Another problem is the predictive value of any judgement made of a teacher in one set of conditions for his performance in quite different circumstances. A student-teacher or a participant in an in-service course can be a fine person during the course, he can be a competent student, interesting and earning good grades. But what happens in the classroom? What happens when he returns to school? Timing is important when evaluating teacher preparation programs and it is a limiting factor when we use feedback to develop courses. Yet we do need a rationale and data and not just the poetic intuition that we always thought was enough.

There are many, many questions about teacher training that have already arisen and which we can discuss. Can we change a teacher in a short course? Is it best to mix people from different backgrounds; in training? in the classroom? A suggestion was made yesterday that it is better to have mixed groups (G. Ramsey). What evidence do we have about this? How can we really get this information?

Another problem is the design, validation and introduction of instruments of evaluation. None of these is easy for underdeveloped countries. I went recently to a meeting here in the United States, of the American Educational Research Association, seeking some solutions to our problems. It was sad but I learned that some of our problems with the construction of instruments are being faced here too. For example work is being done on evaluating teaching practice but it is descriptive and does not take into account several important components. There is not enough money available to prepare the effective and varied instruments which are required to investigate a series of characteristics and to decide just how we can meaningfully discriminate between teachers. We know there *are* differences but what? Where? When? In what situations? What is the contribution of teacher trainers to differences in the classroom?

These are general worries but we have some specific worries in under-developed countries. Let me tell you of some of my experiences trying to organise evaluation units in Brazil. I think I can give you some hints about trying to finance, implement and sell the ideas of a unit. After years of preaching, fighting, struggling, losing sometimes, we now have a unit working on evaluation at the Center in Sao Paulo. We also have a big foundation dedicated mostly to educational research that didn't exist before and we have received some money from the Ministry to carry out evaluation studies.

Some of the problems we face are specific and I think the most important lack in our situation is human resources. How do you recruit evaluators? How do you prepare them? They scarcely exist in Brazil. Even if you have the money and the conditions to organize evaluation systems, you still lack the human resources to do it. A possible solution is to recruit people from other areas such as sociology, social science and psychology. But then they do not know just what it is that we require. And if they are not working as full members of the group, they will be looked upon as external assessors. Unless they are involved from the beginning, feedback will be absent, pre-conceived ideas will be examined and a comparison of the benefits of different approaches and different projects may be lacking. The evaluation programs at our institution are intended not just to *prove* something but to *improve* our courses and procedures. We are interested in what should be not merely what is.

One thing we have already learned is that there is no point in sending someone to be trained in evaluation techniques in a more developed country, for example the U.S.A. or Europe, unless he has had substantial experience of our problems. He must work in our situations, learn what the problems, the needs, the constraints are. With these firmly in mind he can benefit from work outside his own country. Then he can return to make a creative, productive contribution to our situation. It has cost us a lot, in terms of manpower, to learn that it just does not work to say 'You have a fellowship for a year, go abroad, learn to evaluate and then come back and evaluate our programs'. Similarly visiting consultants can be very helpful and offer invaluable advice but they must *work* with us in real situations, knowing the conditions. It is impossible to change the reality if you do not truly know it.

Another problem – and it is not by chance that it is in second place here – is that of financial resources. These are always less important than human resources. Money is in short supply and is not always wisely used. It is part of the Latin-American tradition to produce beautiful documents about our educational system. (Some of my friends will not agree with me but I believe it to be true). Our laws relating to education are very impressive, the ideas are excellent and could apply in any country. But when we move from the administrator's office to the school classroom or laboratory things do not look so good. The constraint of the classroom is very real.

Evaluation can be used as an instrument for improving teaching. A dilemma for a policy maker or administrator is whether to spend money training *more* teachers or *better* teachers. It looks better when you have thousands of teachers trained than when you can point to fewer who are really *well* trained. 'Good' is not as good as 'thousands' in statistical tables. This is a factor when application is made for money for evaluation purposes. Another is the belief that evaluation is a semi-skilled process. Policy makers sometimes take the line 'It looks O.K., it's probably good, why not try it again?' or 'You're good enough to evaluate it yourself' or 'You are a teacher (or teacher trainer) isn't that enough?' I am hoping that things will get easier. The difficulties of evaluation are becoming more familiar – evaluation is becoming fashionable – and money is likely to be more easily obtained.

Another problem is the logistics of the process. It is good to read about wonderful evaluation projects with well defined objectives, clear questions at issue and penetrating instruments. But how do you collect the data, find observers, get computer time – even where can you safely store computer cards? These are questions of detail but essentail detail. The facilities, the equipment, the people and the evaluation instruments all need to be taken care of.

Finally, we do not know the extent of the questions we should ask. Evaluation has sociological, economic and political connotations and it is very hard to get genuine information about our programs, our realities and our problems. Some of our problems are specific to Latin America, others to developing countries and still others to any community. How can we begin? What should we do? Let me give one piece of advice:– Start. Form a group and start working. Your plans will be ad hoc, incomplete, not as good as you would like. Never mind. And when you have some results to show then you will be most likely to get aid from agencies and institutions.

We began in this way. We have no money, no funded personnel but what we do have is students, plenty of them. We want to know what is happening to our students on integrated science courses. So we ask this year's students to gather information about the progress and the behaviour of last year's group. They go to their classes, they observe, they have a few rough measuring instruments, check-lists and so on. This activity forms part of teaching practice, it costs nothing and everyone gains. We want to know the processes by which a new curriculum in Brazil is adopted. What really happened in the classroom to projects such as the PSSC or the BSCS? What became of the people who experienced these courses? Our findings will not be the kind that can be published in exclusive learned journals but they will be important to us.

We all need to know how best to use our resources, especially our human resources. I am not a specialist evaluator, I am only someone deeply worried about educational problems and trying to find some solutions. We need an exchange of information with regard to evaluation procedures and this exchange is an important function of a conference such as this.

SCIENCE TEACHERS' ASSOCIATIONS, SCIENCE INSPECTORS AND ADVISORS – THEIR ROLE IN THE EDUCATION OF TEACHERS FOR INTEGRATED SCIENCE

Report of Working Group Wc

Chairman: S. Adu Ampomah, Ghana High Commission, Nairobi, Kenya.

Rapporteur: Barbara Thomson, Center for Unified Science Education, Columbus, Ohio, U.S.A.

Working Group Wc Tasks:

1. Specify existing roles of science teachers' associations, science advisors, supervisors, inspectors, senior science teachers, and chairmen of school science departments.
2. Identify additional roles which might promote science teaching and the ongoing education of science teachers.

Introduction

The Wc group initially divided into three sub-groups (i.e., Associations, Inspectors, and Senior Science Advisors) in order to look closely at each of the following tasks:

1. Existing Roles.
2. Roles needed to promote integrated science teaching.

Common areas were identified by the three groups after working independently. These commonalities were developed into a diagram which illustrates the important inter-relationships among the various areas.

Definition of Terms

Definition of terms is crucial in communicating. The Wc group collectively agreed to certain definitions for the purpose of meeting the identified tasks. The terms defined are:

1. **Roles**

   Broad areas of responsibility and function.

2. **Integrated Science**

   Integrated science has been defined as those 'approaches in which the concepts and principles of science are presented so as to express the fundamental unity of scientific thought and to avoid premature or undue stress on the distinctions between the various scientific fields'. (1) Such a definition encourages a wide diversity, not only in specific topics chosen for inclusion but also in the overall organization and structure of those programs that are considered to be integrated science. The content and approaches of integrated science programs at the primary and secondary levels will reflect this diversity, while pointing out and emphasizing certain common characteristics and approaches found in most programs considered to be integrated science. Cultural traditions, social and/or economic limitations, and even the personalities and experience of the program developers may affect the degree to which these commonalities are present in any one program, but on the whole these commonalities, not the differences, express what integrated science is today.

3. **Model**

   Scheme or plan within which teachers operate to promote integrated science. Overall plan.

4. **Senior Science Teacher**

   Science department chairmen, science department head, and senior science teachers are used as synonyms even though their roles may have certain characteristics which vary.

5. **Inspectors**

   Supervisors and inspectors were used as synonyms although it is acknowledged that, at times, their functions are different.

6. **Consultant**

   Outside person whose expertise is requested. May be called an advisor in certain countries.

7. **Inspectors, Advisors and Supervisors**

   These three categories will be referred to as IAC's.

Associations

Dissemination of Information

Publications. Associations can produce a variety of publications which will disseminate the concept of integrated science. Associations from various countries already have publications such as journals, newsletters and bulletins. Some associations also produce resource books and bibliographies some of which are annotated.

Meetings. Professional associations organize meetings at various levels; i.e., local, regional, national, and international. Organized meetings provide for contributed papers, panels, symposiums, etc. Written documents sometimes are produced prior to meetings or as a result of these planned meetings.

Career Education for Teachers and Students. Some associations provide opportunities for career dissemination. This may be done through printed documents or planned meetings.

Popularization of Science. Science fairs which are open to all ages promote the popularization of science. A science congress which occurs in some nations also promotes this. Integrated science topics could be encouraged during these sessions.

Public Relations and Interpretation of Science Education. All media should be used by associations to disseminate information, i.e., T.V., radio, newspapers. Associations usually have access to media not easily used by local schools. Good use of this resource can promote dissemination of integrated science. Meetings could also include workshops or other sessions for parents and/or students to improve the public understanding of integrated science.

Information Exchange. Associations have the organizational structure which can facilitate the exchange of information. As previously mentioned, this can be done through publications. This exchange should also include research reports which could be disseminated through associations.

Formulation and Implementation of Policy

The role of associations in the category of formulation and implementation may vary widely in international education. However, many associations are considering taking more active roles in the future. Associations may provide endorsement and assist in formulation and implementation of policies. Position statements on integrated science could be developed. Since some associations assume leadership in recommending certification guidelines, there is also a possibility to establish standards for science education. Associations can be agents of change if all the potential roles are utilized.

Curriculum Development

In some nations, associations may become involved in curriculum development. Other association leaders indicate that this should not be a role so that they can remain objective about new curricular materials. Most associations encourage curriculum development and some help to initiate it.

Teacher Education

Association leaders and members can play many roles in the area of teacher education. The most common way to assist is through in-service workshops. Sometimes association leaders also are invited to advise on new programs for pre-service teachers. Both pre-service and in-service teachers can be helped in the area of integrated science if associations will use the expertise available to them and prepare specialized as well as general conferences and/or workshops.

Professional Status

Peer recognition, program recognition, and school recognition can provide quality integrated science programs by the association. This will encourage quality teachers and programs in integrated science.

Social Responsibility

Different associations assume social responsibility in a variety of ways. Some countries actively seek to establish a humanistic role, e.g., support in replacing education materials which were destroyed. Career education is another area in which many associations work. Integrated science could encourage the study of social concerns through an integrated philosophy.

Opportunities for Integration

Associations provide a structure which could actively promote the vertical and horizontal models of integrated science.* Also, the gathering together of representatives of all disciplines could lead to integrated science discussions and decisions. The communication among leaders in the various disciplines can be promoted by planned association functions.

The Role of Senior Science Teachers

Role

The overall role of the senior science teacher is one of providing leadership for the science department and providing liaison between the science staff and school administration. This is a crucial role when a staff is working in a new area such as integrated science.

Specifically, the leadership role includes many areas:

1. Co-ordinates and unifies staff activities by organizing staff members as a team for optimum utilization of their capabilities, special interests, and aptitudes.
2. Initiates and supports an integrated science curriculum.

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*See 'New Trends in Integrated Science Teaching, Volume 2', Chapter 2.

3. Exemplifies the desirable characteristics which promote integrated science teaching.
4. Organizes in-service courses, seminars for the science staff, and other related departments in order to promote an integration of subject matter.
5. Removes or reduces conflict of attitudes toward integrated science innovation.
6. Advises the administration on professional and personnel matters relating to science teaching.
7. Serves as a liaison between the science teacher and the school administration.
8. Co-ordinates acquisition of materials.
9. Assists and promotes evaluation of integrated innovations.
10. Fosters the interest of students and teachers in activities which popularize and demonstrate the relevance of integrated science teaching, i.e., science fairs, contests, symposium.
11. Co-ordinates the selection, acquisition and maintenance of teaching materials, reference books and journals for teachers. Organizes a departmental library for the staff and fosters the dissemination of information.
12. Arranges opportunities for the staff to visit each other's classes as well as other schools.

The role of the senior science teacher is a very important one. This position can serve as a change agent or can stop innovative practices, depending upon the philosophy of this teacher. This position needs a person who is interested in effective education and assumes good leadership practices. Innovative practices such as an integrated science curriculum can be promoted by a person who assumes this responsible role.

Inspectors, Advisors, and Supervisors

Ideally, inspectors, advisors, and supervisors have been outstanding classroom teachers with experiences and training in curriculum development and research in integrated science. The roles of the IAC's refer only to those which are relevant to the teaching of integrated science. IAC's who will be working in the area of integrated science without previous experiences in this area can be retrained through association in-service work as well as their own initiative.

The ability of IAC's to carry through the following roles is particularly important when working in an integrated science curriculum setting:

1. achieve familarity with curriculum development in science in one's own school, country, and internationally.
2. provide supportive leadership for teachers who are prepared to initiate programs in integrated science. This can be accomplished by supporting and encouraging the integrated science teachers and demonstrating the importance of this curriculum with teachers not yet teaching in an integrated program.
3. catalyze the interaction among staff members both in a school and among schools.
4. insure that the resources required for the successful implementation of integrated science programs are available. This includes both human and material resources.
5. participate in and promote the evaluation of integrated science including the self-evaluation of teachers.
6. promote the appropriate training of teachers, i.e., pre-service and in-service. Universities need to develop optional integrated undergraduate programs.

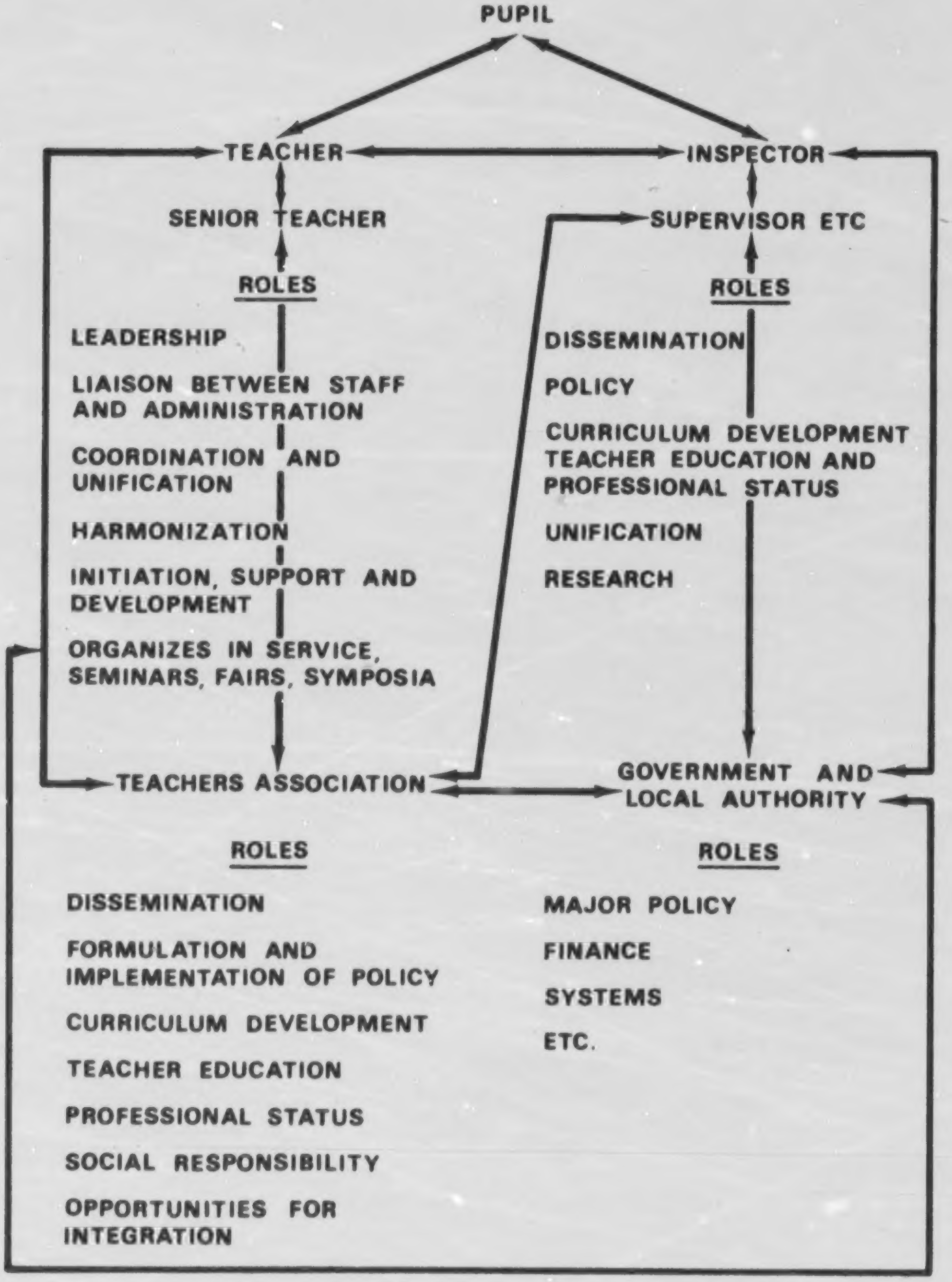
PUPIL
TEACHER
INSPECTOR
SENIOR TEACHER
SUPERVISOR ETC
ROLES
LEADERSHIP
LIAISON BETWEEN STAFF AND ADMINISTRATION
COORDINATION AND UNIFICATION
HARMONIZATION
INITIATION, SUPPORT AND DEVELOPMENT
ORGANIZES IN SERVICE, SEMINARS, FAIRS, SYMPOSIA
ROLES
DISSEMINATION
POLICY
CURRICULUM DEVELOPMENT
TEACHER EDUCATION AND PROFESSIONAL STATUS
UNIFICATION
RESEARCH
TEACHERS ASSOCIATION
GOVERNMENT AND LOCAL AUTHORITY
ROLES
DISSEMINATION
FORMULATION AND IMPLEMENTATION OF POLICY
CURRICULUM DEVELOPMENT
TEACHER EDUCATION
PROFESSIONAL STATUS
SOCIAL RESPONSIBILITY
OPPORTUNITIES FOR INTEGRATION
ROLES
MAJOR POLICY
FINANCE
SYSTEMS
ETC.

Figure 1. Active agencies in a training programme for integrated science

Summary

The roles of the associations, inspectors, advisors, supervisors, and senior science teachers collectively really determine the kind of curriculum which is occuring in the schools around the world. Those who assume quality leadership roles can provide an effective science curriculum. The tasks are complex and time consuming but not impossible. One way to summarize the variety of crucial roles is to say that they are challenging. In pooling the international expertise it soon becomes apparent that the functions which educators assume occur in all countries. They may be under different titles and in different categories but the roles are present. Science educators have historically been curriculum leaders. In the area of integration of science this can again be the case. The roles which could promote a strong integrated curriculum are inter-related themselves. Some roles are more closely related to the pupils than others but directly or indirectly affect the education of our children. (See Figure 1).

At the apex of the diagram are the pupils – our major concern. If an integrated science curriculum more effectively meets the objectives of science education than the conventional discipline orientated program then all of the roles must focus toward the pupils and insure that they have the opportunity to experience this curriculum. The educators who hold these positions must make a decision. With their thrust, innovations can become a curriculum reality. This working group dealt with the human side of the dichotomy and not the materials and subject matter.

The people who are directly involved in curriculum leadership (associations, IAC's, and senior science teachers) eventually determine through their roles the various programs.

THE EVALUATION OF PROGRAMS FOR THE EDUCATION OF TEACHERS OF INTEGRATED SCIENCE

Report of Working Group We

Chairman: David Cohen, Macquarie University, Australia.
Rapporteur: Paul DeHart Hurd, Stanford University, U.S.A.

Introduction

The development and implementation of a teacher education program for integrated science begins with the acceptance of a philosophical position. We make the assumption that an integrative approach to the teaching of science will raise the intellectual capacity of students so they can adjust to and cope with the problems of a scientific-technological based world society. The specialization of research that has brought mankind this far in history now acts as a restraint on general education and, to a considerable extent, upon scientific research itself. It is at the interfaces of two or more disciplines – biophysics, psychobiology, biochemistry, human ecology, astrophysics and more – that much of basic research takes place. Between various sciences there are a growing number of unifying laws, theories, and principles. The generalist scientist, engaged with transdisciplinary problems, projects a new research paradigm for the natural sciences. Furthermore, the public pressure on the scientists to be more socially responsible and to combine efforts with the technologists adds another value component to the scientific enterprise.

Our group was unable to identify viable existing schemes of teacher education for integrated science and so we took as our task the development of guidelines for establishing such programs. These guidelines can then be used to assist in evaluating new integrated programs as they are being developed. They are intended to be suggestive rather than prescriptive, and represent a framework from which a variety of teacher education programs for integrated science can be created. Educational programs are not easily generalized from one country to another. The diversity of idealogies, cultures and educational attainments throughout the world makes it imperative that new directions in teacher education begin from existing conditions and constraints. There is a commonality, however; all peoples desire a higher quality and a more appropriate education in the sciences for their children; integrated science seems to hold such a promise.

PART I

Teacher Education for Integrated Science Teaching

In this section a number of guidelines and criteria are identified by which integrated science teaching programs may be evaluated. These will need to be interpreted somewhat differently for elementary school programs and at the secondary level. The guidelines can be applied to pre-service and in-service programs, although they are written with reference primarily to pre-service education. No one set of guidelines is meant to stand alone or to be more significant than another. Progress toward the new rationale for science teaching must be evaluated on all fronts. This means an examination of: (1) the subject matter and course organization in the basic sciences; (2) the philosophy and content of the professional courses in education; (3) the attitude of teachers towards integrated science; (4) the science curricula within the schools; (5) the achievement of pupils in terms of their ability to use integrative concepts appropriately.

At each phase of the evaluation process, evaluators with particular competencies will be required. Scientists are possibly the best judges of important integrative concepts, laws and theories among the sciences. Teacher educators have a responsibility to see that professional courses for science teachers include topics which support the integrative mode of teaching. External evaluators, such as experts on evaluational techniques, government and local school inspectors, professional associations of scientists, educators and teachers, and representative citizens, have a significant role in evaluating progress toward the goals of integrated science teaching.

Teacher Education Programs

Programs for teacher education consist of a number of elements which are shown in relation to each other in Figure 1.

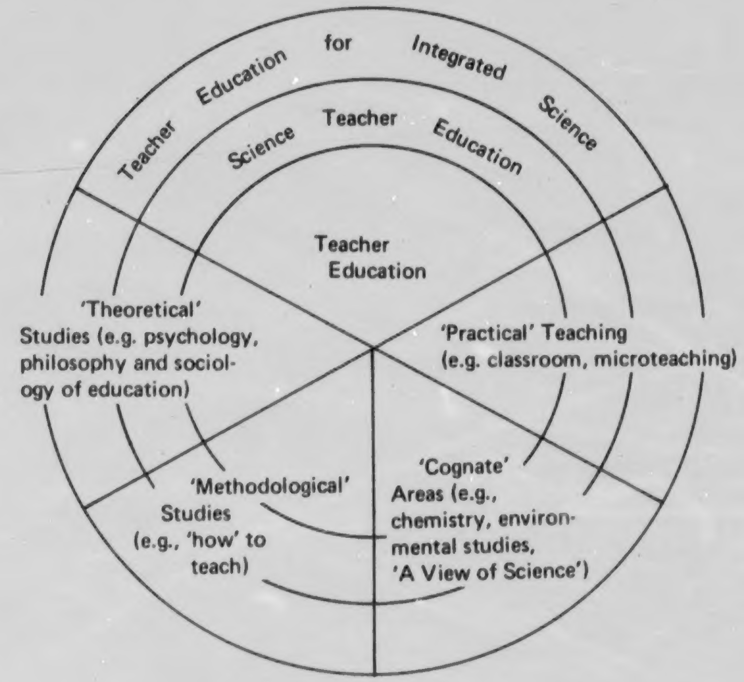
Teacher Education for Integrated Science
Science Teacher Education
Teacher Education
'Theoretical' Studies (e.g. psychology, philosophy and sociology of education)
'Practical' Teaching (e.g. classroom, microteaching)
'Methodological' Studies (e.g., 'how' to teach)
'Cognate' Areas (e.g., chemistry, environmental studies, 'A View of Science')

Figure 1. 'Elemental' Model of Teacher Education

The inner circle represents elements common to teachers of any subject such as, an understanding of child growth and development, and a knowledge of the basic laws of learning and educational technology. The middle area represents the special competencies of science teachers such as a knowledge of one or more sciences, a 'view of science', laboratory management and safety practices, and an understanding of the methods of scientific inquiry. The outer circle represents the special requirements for a teacher of integrated science. This is the area of particular concern in this report; we will *not* be exploring the general problems of teacher education.

The group recognized that the evaluation of programs for the education of teachers of integrated science is a continuous process extending from pre-service experiences through in-service implementation practices. In Figure 2 the relationship of these components is shown along with the feedback loops which are essential for a continuous perfection of the program.

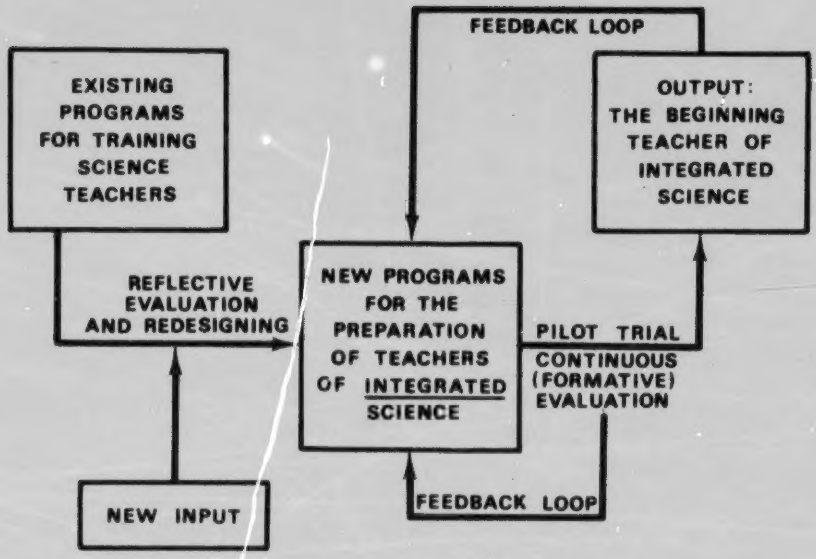
FEEDBACK LOOP
EXISTING PROGRAMS FOR TRAINING SCIENCE TEACHERS
OUTPUT: THE BEGINNING TEACHER OF INTEGRATED SCIENCE
REFLECTIVE EVALUATION AND REDESIGNING
NEW PROGRAMS FOR THE PREPARATION OF TEACHERS OF INTEGRATED SCIENCE
PILOT TRIAL
CONTINUOUS (FORMATIVE) EVALUATION
NEW INPUT
FEEDBACK LOOP

Figure 2. **The planning and implementation of a teacher education program for integrated science.**

A first step in the evaluation process is to examine the existing program for the education of science teachers to determine its relevance for the education of teachers for integrated science. Assuming that integrated science teaching is the goal, the evaluative process is a reflective examination of present practices. 'Reflective evaluation is used to clarify the definition and to refine the criteria for deciding what qualifies for inclusion in integrated science curricula'. [1]

The Basic Science Courses for Teachers of Integrated Science

The basic science courses which are part of the preparation for teachers of integrated science should be organized and taught in an integrative mode. They will differ from discipline based courses in rationale, organization, and the mode of teaching. Integrated courses reflect a holistic view of the scientific enterprise by going beyond unifying concepts, laws and theories between disciplines to consider the philosophy, history and sociology of science, along with the relationship of science to technology, values, and the welfare of mankind. The goal is to present science in contexts which include issues and problems relating to the personal, social, cultural, economic and political life of the nonspecialists. In other words, attention is focused more on 'science for the citizen' than on science for the potential researcher.

These courses are organized in terms of integrating themes. The themes may be pervasive concepts, laws and theories of science such as, evolution, energy, symmetry, structure of matter and others. Other thematic organizations may be the investigative methods of science and problem solving techniques. Decision-making is a useful theme particularly in programs where a major goal is personal or social action on the part of the student. Social and economic issues or problems, such as, pollution, world food supply, personal and world health, population, the 'quality of life', or science and the humanities can provide another kind of integrative organization. A topical organization designed to show interactions between science and technology can also be used, for example, world communication, weather control, transportation, farming and mining the oceans, man's future in space, biotechnology and the possible extension of human life, provide the integrative structure. The organization of science courses along these lines does not imply that the scientist's efforts to display the logical arrangements within a discipline be ignored, but rather that less attention be given to the doctrinaire role, and more attention be devoted to science in the service of mankind. Nor does it mean that the virtues, methods and theories of a science are to be taught with lesser meaning, but that they are presented in a context different from that of the isolated discipline.

The staff of the Institute of Physics, University of Palermo, plans courses for the teaching of integrated science in terms of an assumed set of axioms which serve as general objectives for integrated science courses. These objectives represent the abilities to be achieved by prospective teachers and are as follows:

1 – 'To gain a scientific attitude, i.e., to be able to use the scientific method, in all its different stages'. This objective is interpreted to mean the ability to produce knowledge.

2 – 'To understand the impact of scientific culture in the modern organization of different societies'. This objective means to develop in young people the ability 'to understand many political, sociological and economic aspects of present times, or, in other words, to be able to read news-papers'.

3 – 'To understand the role of science in the historical development of humanity'. [2]

The interdisciplinary character of the program for teachers of integrated science is thus guided by the objectives of the program.

The Center for Unified Science Education in the United States has identified a set of components for integrated science teaching. These components consist of a listing of values, intellectual processes and integrative concepts; see Table I. Note that the elements of a unified science program are not identified by disciplines, but by components which bring disciplines together. [3]

If one seeks to evaluate programs for the education of teachers of integrated science, he should expect to find the science courses built around integrative themes that conceptually relate one discipline to another and which treat science in the context of personal and social affairs. Furthermore, these courses should be organized and taught in the integrative mode. A teacher education program for integrated science teaching that is no more than an aggregate of isolated disciplines is likely not to be adequate no matter how diversified these courses may be.

Professional Education Courses for Teachers of Integrated Science

The pedagogical training for teachers of integrated science needs to be consistent with the rationale underlying integrative education. Courses in the philosophy of education must help teachers understand what is meant by integrative education, its underlying assumptions and its potential worthiness for general education. Courses in the sociology of education, curriculum development and methods for teaching science should include topics and materials that represent the distinctive nature and context of integrated science teaching. It is not enough to identify the educational goals of integrated science; the entire range of subjects in the education of the teacher must be supportive of and appropriate to these goals. The evaluation of professional courses for educating teachers for integrated science begins by examining the goals of these courses for their consistency with the philosophy of integrative education, the appropriateness of their subject matter, and whether they are taught in an integrative mode.

Table I UNIFYING THEMES: CENTER FOR UNIFIED SCIENCE EDUCATION
OHIO STATE UNIVERSITY (U.S.A.)

Values that Underlie Science

- Longing to Know and Understand
- Search for Data and Their Meaning
- Respect for Logic
- Questioning of All Things
- Demand for Verification
- Consideration of Consequences

Intellectual Processes of Science

- Classifying
- Inventing Concepts
- Designing Experiments
- Questioning
- Identifying Variables
- Interpreting Data
- Defining Operationally
- Predicting
- Hypothesizing
- Using Numbers
- Controlling variables
- Observing
- Formulating Models
- Using Logic
- Inferring

Major Concepts of Science

- Cause-Effect
- Equilibrium
- Force
- Matter-Energy
- Organism
- Quantum
- Space-Time
- Cycle
- Evolution
- Interaction
- Model
- Population
- Resonance
- Symmetry
- Entropy
- Field
- Invariance
- Orderliness
- Probability
- Scale
- System

Educational Sociology

Over the past five years particularly, it has become increasingly evident that science teaching should be more concerned with helping young people to appreciate the impact of science and technology on the course of social and economic events in the modern world. Furthermore, science for the citizen should be directed more toward improving the welfare of mankind than displaying the research of isolated scientific disciplines. One purpose for teaching science in an integrative pattern is to help people use science in resolving a variety of science-based social problems.

In evaluating programs for the education of teachers of integrated science, we would expect to find topics that consider social influences on the discovery of scientific knowledge and which discuss the social responsibilities of science – its shift toward a 'moral' science – and the interaction of science and technology.

A teacher who is prepared to teach integrated science in a social context:

1 – recognizes that science reflects as well as stimulates the course of social and economic development: recognizes the role of science in the progress of civilization.

2 – understands that innovation in science and technology may rearrange the political relations and power balance of the world.

3 – appreciates the importance of international co-operation in scientific achievement.

4 – understands that through scientific endeavors there is a likelihood that bonds of understanding between countries may be developed leading to more co-operative efforts among the people of the world.

5 – recognizes that technologic and economic development rests upon the willingness of people to support research in the sciences.

6 – recognizes that social and economic inventions may be necessary to keep pace with and to enhance scientific and technological achievements.

7 – understands that the course of future developments in society will be influenced by achievements in science and technology and can cite examples within his own country.

8 – appreciates the efforts to guide scientific investigation and to control technology development for the well-being of mankind (for example, in medicine, agriculture, public health, and energy resources).

9 – appreciates that the growth of scientific efforts stems from a compelling desire of man to understand his environment and through technology to control nature.

10 – recognizes that discipline judgment on many contemporary social, economic and political problems has rational solutions only in the context of science and technology: there is an interaction between social and intellectual values and the developments of science and technology.

11 – appreciates the essential lag between frontier research and the popular understanding of these achievements and the need to seek ways to narrow the gap.

12 – understands some of the cultural conditions underlying the current antiscience sentiments expressed by young people.

If we expect students to understand what is meant by a scientific-technological society and to deal with the problems generated by these forces, then we must expect that their teachers have had the special training essential to achieving these goals. [11]

The American Association for the Advancement of Science publishes each year a comprehensive bibliography on *Science for Society.* The Third Edition (1972) lists over 2,500 articles and books on the topic. This book has proved useful for developing syllabi for teachers on the subject of 'Science and Society'. [4]

The Philosophy and the Psychology of Education

A philosophy of education is a study of what ought to happen in schools in terms of an assumed set of values. For a century or more, secondary school science has been taught primarily for its value in preparing students for college and for embarking on a career in science. Especially has this been the nature of physics and chemistry courses and to a lesser extent the situation in the biological and earth sciences. Students learned these sciences as disciplines and the investigative skills of value to a researcher were taught in the laboratory. Integrated science is based on value assumptions different from those of discipline centered course.

Arguments about the value of integrated science in contrast to specialized science as a basis for educating future citizens are dealt with in the two preceding volumes in this series of UNESCO publications. [1, 5] A basic course on the philosophy of education for teachers of integrated science should include a consideration of a number of these issues. The question, 'What knowledge is of most worth?' remains as important today, and for about the same reasons, as when first asked by Herbert Spencer a century ago. [6] Social and cultural changes of the past few years have significance for all of education, but especially for science. The present exponential growth of scientific information makes it imperative that we find ways of bringing about a new synthesis for educational purposes. The basis for this synthesis is rightfully a function of the educational philosopher. It is his task to consider the context for the teaching of science and the meaning it has for achieving particular educational goals.

An acceptable course on the philosophy of education for the potential teacher of integrated science should include among its topics: (1) the value of integrative approaches in science for the purposes of general education; (2) man's efforts to develop unifying principles within science; (3) possible contexts for developing a cohesiveness of knowledge within the natural sciences, as well as between science and the humanities, and (4) the place of science and its methods in personal and social action. These topics are illustrative of those that should be included in the preparation of teachers for integrated science.

Integrated science teaching also has implications for the way science is learned. In integrated science teaching the emphasis is upon having students form principles, laws, and concepts which are generalizable beyond the context of the original learning. This means the teacher will need to understand decision making processes as well as those of scientific inquiry. Heuristic and logical thinking, analogy and metaphor become important when scientific information is applied outside a discipline to problems of human concern. Teachers will also need to understand that successful coping with science based social problems is culturally orientated.

The Pedagogy of Integrative Science

A course on the pedagogy of integrative science teaching is crucial to the pre-service educational program. The teacher of this course should be thoroughly grounded himself in his knowledge of integrated science and, furthermore, how it can be implemented in the schools. It is the responsibility of the teacher of science pedagogy to supply whatever is lacking in the other pre-service education courses relative to integrated science. It is in this course that the prospective teacher of integrated science learns the responsibilities of his profession. Again, it should be emphasized that in this report we are not dealing with science teacher education as a whole, but only those aspects which are specially important for the teacher of integrated science.

At the conclusion of this course or these courses the prospective teacher of integrated science should be able to:

1 – state a rationale for integrated science teaching and be able to compare and contrast its educational advantages or deficiencies with discipline based science programs.

2 – formulate a statement of goals for the teaching of integrative science at various school levels.

3 – identify integrative principles of science and relate these to problems or issues in a variety of science and social contexts.

4 – plan various ways to organize curriculum materials in an integrative mode; for example, process, thematic, topic, applied science, man-centered, environmental, project, concept, patterns, issues, problem areas. In another vein the integrative organization for a science program can be thought about in terms of mixed courses (science, values, technology); interrelated studies (human biology and human ecology); unified science (basic principles common to several sciences); correlated courses (common elements in a core program); multidisciplinary (using information from several disciplines); interdisciplin-

ary (using knowledge at the interface of two or more disciplines); transdisciplinary (biophysics, psychobiology, astrophysics, a concern with new systems of knowledge); and there are other schemes such as broad field programs, fused science, co-ordinated studies, etc. The beginning teacher should be aware that none of these approaches is like the traditional 'survey' courses or general science, nor do they represent simply an aggregate of topics without thermatic relevance.

5 – recognize that instruction in integrative science requires attention to deductive processes in which science principles are used to both unify thinking and resolve problems and issues. Integrative science teaching has as its goal helping students carry knowledge into action and to apply it in practical ways. Integrative teaching hopefully provides students with a quality of experience in which thinking and action are interwoven in a rational manner.

6 – identify, select or devise for students learning experiences that are integrative activities. How the course is organized will determine some of these activities, such as working on practical problems, developing projects or dealing with science based on social or ethical issues.

7 – devise tests and other evaluation instruments which demonstrate the students' ability to think in an integrative mode and to apply their knowledge in new contexts. The teacher recognizes that tests provide one of the more important ways that the goals of integrated science are interpreted to students.

The effectiveness of the teacher will depend in no small degree on his own understanding of integrative science teaching and whether he is himself an integrating individual.

Summary of Part I

The pre-service education program for teachers of integrated science must at every point be concerned with presenting an integrative approach to education. In this section a number of these characteristics are identified and in turn serve as guidelines for evaluating teacher education programs designed for integrated science teaching. An effective program moves forward on every front; it is a total institutional program representing a commitment to a particular point of view about the teaching of science for the citizen of modern times. Although the details of the program will of necessity vary from country to country, the educational rationale is more uniform.

PART II

The Effective Teacher of Integrated Science

The development of programs for the education of teachers of integrated science can be evaluated by examining the teacher who is the product of the training program which prepared (pre-service training) or otherwise qualified him (in-service) for a position as a teacher of integrated science.

The evaluation cannot be done, however, apart from a consideration of the complex relations among teachers, teacher education programs, the school in which teachers work, the government, society, and scientific professions. Effective evaluation will depend in part upon establishing lines of communication among these entities not only for the purpose of evaluation but also for using the results to improve teacher preparation. A tetrahedron model was devised, see Figure 3, to illustrate the major components of this communication system. *Teacher education,* includes programs, institutions and personnel; *teachers,* includes both pre-service and in-service;

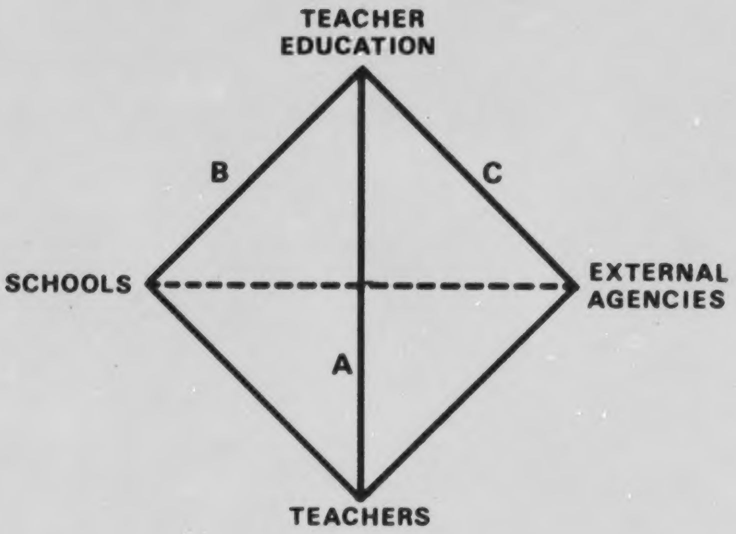

Figure 3. **Evaluation model illustrating essential components and communication channels.**

the *school,* includes pupils, teachers, administrators; *external agencies,* includes hiring authorities, inspectors or supervisors, the professions and the general public. These categories may overlap in personnel, but are distinguished by role. The model shows no one of these categories at the center of the communications systems but provides for all the possible interactions of the four components. The *face edges* (A, B, C) represent (but not the base edges) the principal avenues for evaluation and communication.

One step in implementing this model is to establish effective communication channels between the various components, for example:

A. Between the teacher education faculty and the beginning teacher through:
   1 – The use of specially designed evaluation instruments on various aspects of integrated science teaching, both during and at the completion of the teacher education program.
   2 – Exchange of visits at frequent intervals during the early years of teaching.
   3 – Exchange of correspondence, questionnaires and taped lessons.

B. Between teachers and the teacher education program at various points in time:
   1 – The pre-service level:
      (a) Teacher representatives participate on program planning and revision teams.
      (b) Teacher provides inventory of perceived needs.

    - (c) Teacher supplies commentary on usefulness and relevance of various phases of the program.
  - 2 – First year in-service level:
    - (a) Teacher reports major problems in teaching integrated science.
    - (b) Teacher reassesses pre-service experiences after first in-service year.
    - (c) Teacher assesses adequacy of college follow-up programs.
  - 3 – Five to eight years in-service level:
    - (a) Teacher defines long-term values of his pre-service training.
    - (b) Teacher comments on recent graduates of pre-service programs.

C. Between teacher education staff and the schools:

  - 1 – Teacher education in relation to schools:
    - (a) Teacher educators make frequent visits to the schools.
    - (b) Certain schools choose a continuing relationship with a teacher education institution.
    - (c) Teacher education institution examines reports on new integrated curricula and policies in schools.
  - 2 – Schools in relation to teacher education program:
    - (a) School evaluates product of teacher education program for knowledge of appropriate integrative methods of teaching, learning behaviour and an understanding of the social milieu in relation to curriculum.
    - (b) School staff evaluates the attitude of new teachers toward integrated science, their sensitivity to pupil needs, sense of personal responsibility, etc.
    - (c) School staff evaluates new teacher in terms of skills for devising learning environments and assessing pupil progress, etc., appropriate to the effective teaching of integrated science.

D. Between teacher education program and external agencies:

  - 1 – The teacher and employing authority:
    - (a) Teacher educators visit schools with inspectors.
    - (b) Inspectors report the criteria of their evaluation to the teacher education institution.
  - 2 – Employing authority to teacher education institution:
    - (a) Authority assesses relevance of teacher education program evaluation criteria to the aims and aspiration of the society.
    - (b) Authority conducts surveys of public and professions assessing teacher education programs.
    - (c) Inspectors report on the teacher product and process of the teacher education program.
    - (d) Inspectors participate in seminars at teacher education institutions on methods and curricula of integrated science teaching.

- (e) Authorities assess effectiveness of communication between teacher education institutions and the schools.
- (f) Authorities evaluate the competency of teacher education institutions for in-service training programs for integrated science.

E. Between teacher education programs and the professions:

- 1 – Teacher education institutions maintain liaison with science societies and teacher associations by creating posts for co-ordinators, liaison officers, etc., who will co-operatively seek to refine programs for integrated science teaching.
- 2 – Teacher education institution surveys attitudes and opinions of members of science professions for improving the integrative aspects of science courses for teachers of integrated science.

F. Between the professions and teacher education programs:

- 1 – The accreditation agencies evaluate pupil learning in terms of the goals and objectives of integrated science teaching.
- 2 – Voluntary political and non-political professional associations monitor values and criteria of teacher education programs for integrated science teaching.
- 3 – Scientific institutions co-operate with teacher education institutions to improve research on integrative education.

G. Between teacher education personnel and the public:

- 1 – Teacher education to public:
  - (a) Teacher educators attend public meetings on educational issues.
  - (b) Teacher education institutions invite public or local community representatives to seminars and meetings.
  - (c) Teacher education institutions provide public with information about its programs.
- 2 – Public to teacher education personnel:
  - (a) Pupils react to goals, content and achievements by questionnaires, inventories, etc., through samplings conducted by teacher education institutions.
  - (b) Parents react to goals, content and achievements by questionnaires, etc., and are represented in teacher education advisory boards or committees.
  - (c) Parents and pupils contribute feedback by anecdotal report, suggestion boxes, and through tax referenda.

Summary of Part II

The development and continuous refinement of a program for the education of teachers of integrated science can be achieved by critically examining how the product of the endeavor, the teacher, functions or performs. A teacher well-trained for his task of teaching integrated science is subject to a number of constraints which may limit his capacity to teach as well as he knows how. Integrated science may be a new idea to parents and pupils and they may in turn resist changing traditional courses. The teacher licensing agency may not accept the essential distribution of preparatory courses among several sciences and insist upon a concentration in one discipline, thus limiting the teacher's capacity to manage integrated science courses. School administrators may worry as to whether integrated science courses will be accepted as qualifying for college or university entrance. The model displayed in Figure 3 represents the range of factors which seem necessary to control and assess in judging the effectiveness of a teacher education program for integrated science teaching.

PART III

Needed Evaluation Data and Instruments

The working groups at the Conference recognized at the outset that there is a sizeable range of instruments and procedures for assessing teacher performance, generally, and in the sciences, specifically. What the groups did not find were instruments specifically designed to provide data on questions related to the teaching of *integrated* science. There are many tests that might prove useful to determine whether the teacher's science background in biology, chemistry, physics or earth science meets some stated level of acceptance. What is missing are the tests which might provide evidence of the teacher's ability to identify integrative principles which serve to unify these sciences. There are tests which can be used to assess the teacher's understanding of inquiry processes in sciences, but here again, of equal importance are decision making processes and these are not a part of the traditionally used tests.

To evaluate the worthiness of a teacher education program for integrated science, instruments are needed built upon the philosophy and goals of the program. There is a danger in using tests developed for discipline based instruction as they were devised from a contrasting point of view and with different objectives in mind. Until such time as appropriate instruments can be developed the procedures suggested in Parts I and II of this chapter would seem to provide a mechanism for the monitoring and improvement of integrated science teacher education programs. The groups recognizes that there are many competencies, skills and attitudes, and much basic information common to all good teaching and that there are useful instruments or procedures for judging the effectiveness of the teacher along these lines. Our concern, however, is limited to devices specifically orientated to integrated science teaching.

The group notes the need for a wide range of test instruments, evaluation data and information about the teaching of integrated science and the planning of supportive education programs. The group, therefore, recommends that a publication be supported by UNESCO which will report information about integrated science teaching, such as:

1 – Evaluation instruments that have been developed, including their validation procedures, possible uses and limitations and source; both cognitive and affective measures are needed.

2 – Official teacher certification requirements and the examining philosophy or criteria that are used for licensing.

3 – Teacher education programs for integrated science and the effectiveness of the various evaluation and communication components.

4 – Activities of professional associations; the responsibilities, programs and roles they are assuming for the development of teachers for integrated science.

5 – Activities and experiences of teacher education institutions in fostering programs of integrated science, such as descriptions of curricula, samples of examinations, and other relevant information.

6 – Elementary, middle and secondary school teachers should be encouraged to report their experiences with integrated science.

7 – Teacher education films, audio and video taped lessons of integrated science teaching so that these may be analyzed by teachers and educators.

8 – Listings of schools, colleges and universities offering programs of integrated science, including conferences where integrated science will be discussed.

9 – Reports of research that are concerned specifically with the philosophy, goals, subject matter, curriculum organization, teaching, learning and evaluation of integrated science projects.

The groups recognizes the great importance of sharing ideas throughout the world if significant progress is to be made in the establishment and the improvement of integrated science. It would like to see UNESCO extend its activities to include an information resource center or clearinghouse on integrated science teaching. This may be a function which UNESCO might sponsor in connection with existing science education centers in several countries.

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THE ROLE OF SCIENCE TEACHING IMPROVEMENT PROJECTS AND CENTRES IN THE PREPARATION OF TEACHERS OF INTEGRATED SCIENCE

Working Group Wh.
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The papers submitted for the consideration of the group provided case histories of several projects and details of a number of centres (notably in the Philippines, South America, India, West Africa and the West Indies). Since, in addition, the membership included people from a wide variety of centres and projects an extensive experience was available to the group.

A. Science Improvement Projects and Teacher Education

A science teaching improvement project is an important vehicle for effective interaction between all the parties involved in the process of science education. One important consequence of this is that participants – and especially teacher participants – grow in ability as the Project matures. This is true as much for the 'trials teacher' as for the teacher who serves as a member of the development group. In each case the participating teacher is involved in a situation in which he is forced to use his creative talents to the full. It follows that a conscious effort to reproduce a situation in which teachers need to be innovative in the reality of the classroom situation has particular importance in improving the quality of both teaching and learning.

Curriculum development projects effect changes in the attitudes of participating teachers towards the children they teach. For example:

> *"the nature of the Philippines Integrated Science program creates a special problem for the teacher who wishes to implement it. Students taking the Integrated Science course work in small groups rather than in large groups of fifty or so students. So to teach Integrated Science properly, a teacher must be willing to delegate to the student many duties that were formerly his alone. The teacher must learn the skills that are required of one who deals with individuals or small groups".*[1]

Such a teacher will be much less authoritarian as he sees his role change to that of a consultant to his pupils. This is a lot to ask of a teacher for it involves insecurity – especially in those areas of integrated science with which he is least familiar. He needs help in the handling of such awkward situations as might arise and this help is due to him, either from the project itself or from a science education centre, if his initial training failed to provide it.

Evidently teacher preparation for integrated science teaching must develop that perceptiveness in young teachers which will ensure that they are aware of the needs of individual children.

The effectiveness of the science teaching improvement projects depend on:

(i) the involvement of practising teachers,

(ii) the use of feedback from trials conducted in typical classroom situations,

(iii) the realisation that a science course is a growing, dynamic organism.

When in the stage of implementation, a project will be effective if:

(a) the teachers are convinced that it was developed in response to a real need,

(b) it has a well developed, concurrent programme of teacher education,

(c) there is a well organised plan for disseminating information,

(d) more and more teachers become involved as the materials become available.

These resource materials will include equipment. The design and testing of such equipment must be an integral part of the improvement project's task bearing in mind that it is always wise to illustrate principles with familiar materials.

> *"Unless teachers have been trained to observe, unless their senses have been sharpened, they will rely on the texts and the lecture notes that they have faithfully copied during their training. They will not see the parasitic growth on the trees, or the salt in the dusty soil. They will not feel competent to mention kite flying or hot air balloons in their lessons as they illustrate key principles. They will not recognise the relevance of the bamboo carrying-pole. Science will continue to be the stuff to which science text-books refer".*[2]

Projects in related subject areas and, indeed, in apparently unrelated ones, should be co-ordinated. This makes it easier for the school administrative system to understand the changes which are foreseen and so to resist the pressures exerted by curricular salesmen.

The training of teachers of integrated science is largely an education for change. These young teachers must be given the opportunity to work with the new curriculum materials during their training; and the methodology of teacher education must be, and must be seen to be, compatible with the methodology appropriate to the new programmes. Teachers are notoriously prone to teach as they were taught. Only by teaching them in the way that we expect them to teach can we ensure that the teachers of the future can implement effectively and with understanding the new programmes which are yet to come. One model for arranging this important outcome is to be found in the Science Teacher Education Project which is based at the Universities of Leicester and Reading, U.K.

No single model can serve to describe a best way of introducing new programmes to teachers, to administrators and to parents. But it is worthy of note that the American Association for the Advancement of Science and the Intermediate Science Curriculum Study have prepared in-service guides to be used by teachers, administrators, supervisors and teacher educators. These guides cover the material content as well as the techniques. Other approaches were those of the Nuffield Physics Project with its series of films for teachers and of Project Physics with its Classroom Vignette films of teaching situations. But all programmes have knowledge of men and women who have been involved in their development work and who possess considerable funds of knowledge and expertise which can be applied to this task. Teacher educators would be wise to tap this recource, for these people will possess that intimate knowledge of local needs and local problems which needs to be taken into account in successful curriculum development; as an example of such needs the inter-relationship between a developing integrated science programme and local agriculture and horticulture was cited.

Science teaching improvement projects must consider with the greatest care and sensitivity the problems presented by the language in which the subject is to be taught. Those languages which are not rich in roots present a special problem in this respect. It is important that project teams should be familiar with work done elsewhere, for successful strategies for handling the problem have been developed, notably in India and Thailand. The importance of evaluation can hardly be over-stressed; continuing feedback from field work provides a salutary check on progress and on-going evaluation is now recognised as an essential part of any project.

All these factors are of importance to the teachers and deserve their place in their education, whether pre-service or in-service, formal or informal. Participation in project development has become an important part of the training of any teacher. However it is evidently not possible to involve the entire teaching force of a country in a curriculum development programme and so the responsibility of the project team to provide materials designed specifically for use in pre- and in-service courses is a heavy one. If a pilot project is not to fail when implemented on a wide scale it must take these steps to avoid a serious loss of fidelity.

B. Science Education Centres and Teacher Education

Before considering the role of science education centres in teacher education, the group found if necessary to define that role in terms of the function which might be appropriate. This provided an unusual opportunity to discover whether such functions were, in fact, those recognised as important by representatives of Centres who were participating in the Conference.

1. An Analysis of the Work of Science Education Centres

Introduction: Pertinent information about the organisation and functions of thirteen science education centres (selected at random among those represented at the Conference) was collected.

Organisation: Ten of the thirteen centres are located at or in universities. Furthermore, practically all ten of these are also funded by and are administratively responsible to the university. All but one of the ten were established by the university. This one exception (Barbados) was founded by a science teachers' association.

The three centres not at universities are the Vikram A. Sarabhai Community Science Centre, Ahmedabad, India, the Afghanistan Centre located in the Ministry of Education, and the Birmingham (U.K.) Centre located in a former school and funded by the local education authority.

Finance: The majority of the Centres is supported financially through university budgets. However, two of the centres (Cecine in Brazil, and the one in India) have highly diversified funding from the Ministry of Education, the university, overseas agencies, private foundation and the community.

Facilities and staff: Almost all the centres examined possessed a library, workshop facilities, laboratories, an audio-visual centre and an exhibition area. The Birmingham (U.K.) Centre was unique in having a social centre to encourage informal meetings among the teachers from the city's schools.

Functions: The working group had identified fifteen distinct functions likely to be appropriate to a science education centre. These were:

1 – The pre-service preparation of teachers.

2 – In-service education.

3 – Providing a consultation service to (a) schools, (b) higher education institutions, (c) the community, (d) local or central government.

4 – (a) Undertaking research relevant to its other functions.
  (b) Providing for liaison between schools, teacher training institutions and research teams in (i) research in science education and (ii) curriculum development.

5 – Producing instructional materials for (a) curriculum development projects and (b) other needs.

6 – Maintaining a library of resource material.

7 – Evaluating:
  (a) course materials at school level,
  (b) teacher education courses.
8 – Designing and building prototype equipment.
9 – Organising science clubs and fairs.
10 – Providing courses for teacher educators.
11 – Initiating other science centres.
12 – Utilising radio/TV for the promotion of projects.
13 – Providing guidance in the field of assessment.
14 – Providing facilities for outside groups of students or teachers for meetings, conferences etc.
15 – Providing for communication with Science Teacher Associations.
16 – Providing informal social facilities.

A large proportion (one half) of the centres are involved in pre-service training of science teachers; all but one provide in-service activities.

Again, one half of the sample carried out research in science education and all but one are developing instructional materials.

A disturbing feature of the analysis is the low involvement of the centres in the design of appropriate science laboratory apparatus. Only five reported strong activity in this important aspect of science education.

Another relatively neglected area seems to be that of science clubs and fairs. Over half of the centres took little or no part in encouraging these. The same neglect appeared in regard to radio and TV – only one centre (in the Philippines) reported significant emphasis on this activity.

In addition to the detailed survey described above, a simple questionnaire attracted information about the function of 38 Centres distributed among 23 countries. This confirmed, in general, the results of the sample survey, the one significant difference being that links with science teacher associations were reported by 21 of these centres.

2. The Work of The Group

The several functions of the centres as described above were then considered in detail with special regard to role specification, staffing and resources. It was agreed that important emphasis should be given by the centres to the encouragement of social relationships between teachers of science. It was observed that the widely varying degrees of sophistication among the centres examined made it very difficult to identify any generalised staff profile.

1. Pre-Service Training

A centre plays an important part as a mediator and an integrator between the departments (or faculties) of education which may be responsible for the professional preparation of the teacher, and the specialist subject department responsible for his scientific education. It was possible, and examples were noted, for the Centre itself to provide some or even all of the professional training. It was thought essential that the staff members of the science department should be involved in the work of the Centre, accepting a well-defined role in the training of the student teachers.

2. In-service Training

The resources (which might include school-type laboratories, libraries and other resource facilities, seminar rooms, workshops, etc.) of a science education centre ensured that its in-service programmes were provided in any environment closely matched to the needs. Moreover, such a centre was likely to have the administrative machinery which would support the mounting of such programmes and which would enable it to act as a clearing house for information.

Three examples were considered. In Sierra Leone finance for in-service courses (typically lasting four weeks) was provided by the Ministry of Education, whilst the co-ordination of the courses within the regions was the responsibility of the Institute of Education with the Science Teaching Centre providing staff members and planning. The local Science Teachers Association also arranged some in-service work.

In Nigeria, the centre was responsible for five different programmes, all concerned with the Mid-Western Nigeria primary science project:

(i) one year in-service courses for primary school teachers with no background in science,

(ii) three month courses for primary school teachers involved in the pilot project,

(iii) a one year course for headteachers of primary schools in which the emphasis was placed on the teaching of mathematics and integrated science,

(iv) a three month course for all assistant inspectors of education, designed to help them to extend pilot project activities to all schools in their area,

(v) short courses for science teacher educators from teacher training colleges preparing teachers for work in primary schools (see also (10) below).

In Israel, the Science Teaching Centre was one of three bodies providing in-service education. It was responsible for work with teachers in middle and high schools.

The importance and desirability of up-grading the education and the qualifications of serving teachers of integrated science was stressed in relation to the Centres, which are in a strong position to take effective action.

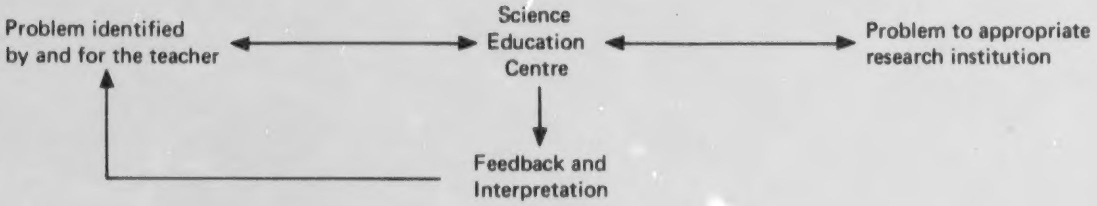
3. The Provision of Consultation Services

The extent of the possibilities for involvement is great; examples of what can be done include the production of news-letters directed to a wide range of diverse targets, the development of resource materials, open lectures on major issues, film shows, fixed and travelling exhibitions and the use of local radio and TV. In the latter case, production assistance might be furnished and feedback from schools etc. arranged. Evidently these activities will require the services of educational technology and links with the media.

In addition to serving as an effective link between schools, higher education, local and central government and the community itself, a centre can also act as a bridge between the needs of local industry and the vocational schools of the region.

4. Research

Research linked with a Centre was likely to follow teacher identification of a real need. The Centre itself could then undertake the research on behalf of and with the co-operation of the teachers, or it might be able to direct the teachers to the literature where the problem was already discussed, or it might direct the teacher to the appropriate research institution. It's role would be largely that of a communication channel, simply represented in the flow chart:


Problem identified by and for the teacher
Science Education Centre
Problem to appropriate research institution
Feedback and Interpretation

Proper areas for such research included curriculum development and evaluation; research into the learning process involving local teachers and children; research into the validity of claims made for competing science courses; research into teaching methods and assessment.

This work would demand an index of sources and other reference material, good links both with schools and research institutions, adequate clerical assistance and, possibly, access to a computer and data storage and retrieval systems.

5. The Production of Teaching Materials

> *"Teachers' Centres can undertake the task of shaping and evolving the scientific content of the new curriculum material suitable for dissemination in schools. In doing so attention may be given to three important aspects: (i) the social and cultural backgrounds of the majority of pupils in the district, (ii) the graded development of the curriculum material for maintaining continuity in the courses and (iii) proper feasibility studies capable of accepting feedback both from participating pupils and teachers".*[3]

Having explored the needs, a Centre has a number of courses of action open to it. It may refer the need to some other suitable organisation, itself providing the co-ordination which will be necessary, or it may itself develop the new programme, or it may act as host for a group especially established to meet the need.

It may develop specific materials on request from other institutions (for example, a teachers training college may require materials which could be used to introduce student teachers to a new school curriculum); it may produce resource material to meet a special but limited need (for example, the introduction of the System International to schools); and will certainly wish to maintain effective contacts with groups working in the same and cognate fields.

To meet these requirements, the staff of a centre would need to include experienced teachers with an understanding of educational research, a wide background of expertise in the several scientific disciplines as well as in the integration of these. A project in integrated science must have an integrated scientist as co-ordinator.

The team will require access to a laboratory, a library, a resource centre, ready access to schools, ample secretarial assistance and technical assistance. The latter should be appropriate to the sophistication of the project and its intended publications. It might include laboratory technical staff, a photographer, a designer skilled in typography, an equipment designer and so on.

6. Library of Resources

This should embrace (a) a reference collection of curriculum materials (texts, guides, audio-visual materials of various sorts, laboratory equipment), (b) a loan collection of selected materials for use by teachers in schools and (c) a significant collection of resources specific to the locality served by the centre and designed with environmental science courses in mind (e.g. flora, ecological surveys, agricultural surveys, industrial information etc.).

The staff members responsible may include an experienced librarian but will certainly need to combine experience of schools and their needs with wide background knowledge of the sciences, skill in reviewing and sympathy for current trends. They will need storage facilities appropriate to a wide variety of materials, including multi-media kits. Ideally this resources centre should be sited centrally and in such a position that expansion to meet the growing demand is readily possible.

Examples cited included the Science Centre for Schools in Jamaica, the Lawrence Hall of Science in California and the International Clearing House at the University of Maryland, U.S.A.

7. Evaluation

Two roles were identified: the evaluation of course materials and of teacher training programmes. Whereas the former requires the Centre to act as a communication channel providing total feedback from the schools using the new materials to the curriculum developers, the latter will involve the Centre in questions of teacher effectiveness and, possibly, in the diagnosis of teacher weakness and teacher strength.

8. Apparatus and Equipment

A Centre will be in a strong position to ensure that local resources and industry are used effectively in the production of apparatus for science teaching. In some cases that apparatus will even have been developed within the centre. In addition, a Centre will be able to offer schools and their administration competent guidance on laboratory design, on the evaluation of new equipment and on its purchase. For this function, there must be access to a well equipped workshop, (with access to specialist facilities when required), competent apparatus designers and craftsmen who can build and test prototype equipment, and access to science teachers for advice and testing in the real situation.

9. Science Clubs and Fairs

Ideally, these are based in and initiated by the schools. Nevertheless, a Centre may help by taking initiative itself and offering help, suggesting ideas and encouraging the participants; acting in a support role. For this an exhibition area within the Centre would be desirable.

10. Teacher Educators

A Centre should be involved in helping college and university teachers to develop their knowledge and understanding of integrated science as a school subject. This may require the Centre to organise seminars, conferences and workshops specifically for this purpose. It is desirable that the attention of the teacher educators should be focussed on the philosophy, the general aims and the specific objectives of integrated science programmes in a way which ensures that the future teachers approach their science teaching in a broadly humanistic way.

11. Initiation of Other Science Centres

Science Teaching Centres often grow by stages. An example of this extension of a network of Centres comes from the Philippines. There the focus has been firmly on institution building rather than on the training of individual teachers. As Professor D. Hernandez points out in her paper:

> *"There are 25 selected teacher training institutions which participate in the Science Education Project of the Philippines. These have been sending members of the faculty to the University of the Philippines Science Education Centre to participate in an 18-month teacher education programme which leads to a Master of Arts in Teaching degree. The institutions receive equipment and some books for each of the major subject areas . . . The next phase of teacher education is conducted in the home institutions of those participants. They are expected to improve the undergraduate programmes in science teaching and to conduct various types of in-service programmes for teachers in the geographic areas served by their institutions. Five of the 25 participating institutions have been designated regional science teaching centres and four additional ones will become operative in 1974".* [4]

12. Utilisation of Radio and TV

See paragraph (3) above.

13. Assessment

A Centre can be a source of knowledge and expertise in the field of testing, both at the theoretical and the practical levels. It can create and maintain question banks and put these at the disposal of its teachers (as is done, for example, in Argentina by I.N.E.C.); it can organise workshops ('shredders') on item writing; it can provide technical assistance in the analysis of test data.

These activities will require it to maintain a library of relevant material, a bank of tested items and the necessary analysis equipment as well as to appoint a staff member who is skilled in the field.

14. Facilities for Conferences and Meetings

Enrichment classes for pupils, for teachers and for student teachers were seen as needs additional to the more formal provision already described. Such events would provide additional opportunities for social and cultural contact among the participants. And this would require, in addition to laboratories, seminar rooms, conference rooms (with projection facilities), comfortably furnished common-rooms where teachers might relax. As K. B. Shah pointed out:

> *"The Centre is also a place where fellow-teachers trying out the same course get together. The exchange of ideas and experiences between these teachers clarifies a number of difficulties faced by them and thus strengthens the confidence of the teachers and their faith in the course".* [5]

At certain times, this may require access to residential facilities (as, for example, at Chelsea Science Education Centre, London, U.K.).

15. Links with Science Teacher Associations

Science Teachers Associations can be powerful allies in the work of the Centre and every opportunity should be taken to encourage the participation of the local or the national association in the work of the Centre. This can produce extremely valuable good-will. Courses organised jointly with the Science Teachers Association may be very effective means of strengthening both the formal and the informal links with schools.

The Working Group saw the Science Teaching Centres as powerful agents for good: it was felt that the Centres should be all embracing and not confined to one science or even to integrated science; neither should they be confined to any one level for they provided the only machinery where teachers from the primary, the secondary and the tertiary levels of education could meet to consider common problems. Moreover, as Dr. Hernandez said in her paper:

> *"Perhaps because science teaching improvement centres are new, they tend to be more flexible than existing teacher training institutions, and have therefore succeeded in introducing innovations in those segments of the teacher education programme that they control".*

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DISCUSSION AND COMMENT AT PLENARY SESSIONS RELATING TO THE IMPROVEMENT AND EVALUATION OF TEACHER TRAINING FOR INTEGRATED SCIENCE

What should we do, in practical terms, to improve teacher training, and how do we know that we have been successful? These two issues were at the heart of most of the discussions at the conference. Time and again speakers came back to the practical issues facing teacher trainers in designing and executing courses for experienced and for inexperienced teachers, and time and again answers to these questions depended on what we mean by integrated science courses and on the procedures by which we evaluate the courses themselves. At the pre-service level there is a long history of training teachers for the separate sciences. Few have been entirely satisfied either with the procedures or the results of training and it is commonplace for teachers in the schools to scorn the activities of colleges of education. In doing so they undervalue their own expertise. Teaching is a demanding job, science teaching is arguably the most difficult job of all and integrated science teaching demands levels of knowledge and understanding which exceed those of the average teacher of science subjects. A teacher expecting new recruits to his school to be able to handle new materials, new methods and lively (possibly ill-disciplined) children with total confidence and skill is asking too much. It is like asking someone who has just taken his driving test to take over a Grand Prix car in a motor race.

The new demands of the schools (and ultimately of society) ask more than ever before of new entrants to the profession. They ask more of the training establishments and more of existing teachers not only as practitioners but also as partners in helping their new colleagues to cope with the school situation. A new teacher has usually a long way to go before he can claim to be operating at his maximum potential. And now the changing scene in education prevents him coasting along secure in the knowledge that past experience is all that will ever be needed in the future. The in-service training discussed in Part 2 is required at quite short intervals.

The discussion following Miriam Krasilchik's talk was a lively as any throughout the whole ten days. The straightforward, jargon-free presentation pin-pointed many of the possible ways of evaluating courses and indicated the many constraints under which the evaluator must operate. Her pragmatic advice to get started on the evaluation process even if the available evaluation instruments are weak was seized upon by many as a key to progress. M. Pentz emphasized that evaluation is required of a course *as it is.* A rough first approximation at finding out how something works is better than an elaborate scheme which might be available in ten years' time. Rigorous evaluation procedures might take so long to develop that the courses under investigation could change and the evaluation become quite useless. In changing situations ad hoc procedures can be more useful than fully developed ones. Pentz also supported Krasilchik in her insistence that outsiders cannot evaluate as creatively as people involved in doing the thing to be evaluated. The involvement of 'experts' from universities, technical colleges or elsewhere as members of teams producing materials and systems leads to much more effective evaluation work than could have been done from 'outside' – and it leads to the production of 'amateur' evaluators.

This latter development is an important one and might be taken further by in-service programmes. Integrated science teaching schemes tend to have flexibility built into them. Many syllabus makers and project leaders encourage individual teachers or small groups to make choices, to select options or to vary the courses. If a teacher is to do this to greatest effect he will need to monitor consciously the changes and their effects. Amateur evaluators can function at all levels, in combination or alone – but they will function most effectively if they are well informed about the choices and options of the course and also about the choices and options available as evaluation procedures. They need practice and contact with people who are in close touch with the classroom and school laboratory but who have developed an expertise in effective evaluation.

L. Elton believed that the problems of evaluation are general and that the differences between developed and developing countries in the availability of appropriate resources are not as great as is sometimes thought. Some resources of developed countries such as number and qualification of science teachers and the provision of laboratories and materials are quite different from those of developing countries – but this is not necessarily true of evaluation techniques. In this context G. Ramsey pointed out that all countries have access to one of the best evaluation mechanisms – human subjective judgement. Teachers knowledgable about the issues and given confidence can comment constructively about their teaching and initiate change to which they feel committed by virtue of their involvement. Analytic and scientific methods of analysis need the insight and support which subjective judgement can provide.

Elton distinguished between changes in the content of syllabuses and lessons and changes in teaching style. It is easy to determine whether *content* has changed and in what way. It is much less easy to discover whether *teaching style* has changed and if so in what way. We need to be able to probe changes in style for many reasons. For example, the teacher trainer might ask two questions which will influence his own plans and behaviour: 'Can a short in-service course change a teacher's behaviour?', and 'Can a teacher whose behaviour has been changed maintain this change in an unaltered environment?' To both questions Elton offered a tentative 'No', and concluded that we either need revolutionary changes which can easily be detected (and if desired, enforced by inspectors, etc.) or evolutionary changes monitored by a sensitive teacher. In matters of policy of this kind there may be differences in requirements in different parts of the world but ultimately sensitive, thoughtful teachers intent on doing what is best for *their* pupils would seem to be most needed.

R. de Llopis Rivas called for a definition of the qualities we would like to see in a teacher of integrated science and a description of the stages through which a teacher behaving in a traditional way must pass in order to achieve these qualities. She noted a first stage, in which a teacher presents information necessary for a pupil to pass examinations, and further stages where the teacher implements new programmes, prepares new materials, improves the curriculum and incorporates contemporary social issues. If we are to use evaluation techniques we need to be clear what we are looking for. F. Watson was in agreement and called for measures to describe:

1 – (a) a teacher; (b) a science teacher; (c) an integrated science teacher.

2 – The functions of a teacher: e.g. knowledge, understanding and comprehension of

(i) the subject (science); (ii) the philosophy of science; (iii) psychological theories applicable in learning and teaching.

He drew attention to the many variations (at least 137) of the Flanders Interaction Schedule which can be used to record teacher and pupil behaviours and noted that some record actions during laboratory sessions. In fact there are many tests which could be used when evaluating the effects of the introduction of new courses and methods but, unfortunately, they are widely scattered and inaccessible. A list of such measuring instruments with some indication of their purposes and limitations would be valuable. J. Mitchelmore noted that we can either adapt existing instruments or devise quite new ones. There are at present very few in the integrated science area but a research program or series of working parties might concentrate on adapting existing evaluation instruments to the needs of integrated science teaching. Creating new tests and schedules from scratch is a laborious, time-consuming task and may not be necessary as so much general work has already been carried out with some measure of success.

The question of teacher performance on pre-service courses as compared with performance in school was raised by F. Egger. How useful is it to evaluate a teacher in training? What predictive value will the results have? L. Baggerly asked if *any* grades in a pre-service course are related to subsequent performance and Professor Krasilchik replied 'Ask me again next year'.

L. Blessing voiced a concern of many teacher trainers attempting to evaluate the performance of their students. In some of the best school science periods the teacher seems to do nothing, yet he is all important. Judging teaching capacity in terms of formal 'chalk-and-talk' lessons or virtuoso demonstrations may emphasise teacher behaviours which are easily observed and assessed, to the disadvantage of the more subtle skills.

The discussions about evaluation were energetic and constructive. It was widely recognised that there is a need to evaluate courses and teacher behaviours but it was also acknowledged that there is still much to do before we are clear about evaluation procedures, indeed there are still differences of opinion about the desirable attributes of the integrated science teacher and what constitutes a first class integrated science scheme. Tests and questionnaires which search and probe are needed as well as tests which purport to measure precisely, well defined components of teacher behaviour.

The conference was however optimistic about the value of evaluation techniques. Not in the sense that perfect instruments will ever be produced but in the sense that serious thought about evaluation, in consultation with people actually doing the teaching job, will lead to greater understanding of the constraints and the opportunities which exist in any teaching situation. Firstly we need more knowledge about integrated science in school and secondly we need much more study of the problems and possibilities involved in training teachers for integrated science at all levels.

J. Goodlad emphasised that school is a society and that the introduction of integrated science will cause substantial improvements only if it is seen in the context of the whole life of the school. S. Adu-Ampoma took this principle further and pointed out that school is a society within a society. In developing countries in particular, school systems often operate in a 'closed' way. They produce scientists, science educators and others who are so insensitive to the needs of the society and the forces operating in it that the society has almost lost faith in and respect for them. He hoped that the training of integrated science teachers would prepare them to accept a role in relation to their own society and that they will be able to function in a more relevant and effective way than those in whom many have lost faith. Adu-Ampoma's plea that developing countries should educate their integrated science teachers in accord with the aspirations and realities of their own society has implications for workers from developed countries seeking to help in the educational systems of others. Aid which results in the imposition of an alien system of values or actions is of doubtful value. As so often at this conference, the solution seemed to be to work together as partners, one side offering knowledge and experience gained in a developed country and the other side consciously incorporating the strengths and aspirations of its own nation.

J. Kusi-Achampong, however, pointed out that in fact one's professional and economic status are not easily separated and that aid personnel come from the richer countries and are seen (often by themselves and their partners) as the 'elite' of the education enterprise. Local teachers are not always given the attention they merit.

The varied and sometimes conflicting roles which teacher trainers have to play were raised by J. Grambs. Those involved in preparing teachers for the classroom and laboratory are usually aware of the social context in which they will work and the frequent need to change it. But they are also aware that the new teacher must function in the system as it is. The teacher educator seeking the best practice is often ahead of the field and thinking beyond the present competence of many teachers. Teachers need first to be able to cope with the daily pressures and secondly to reconsider their functions and purposes. Again the solution seems to be a blurring of the boundaries between school and college and the on-going involvement of teacher trainers with teachers in their schools. All parties have much to teach and much to learn. M. Eurin noted that inspectors and supervisors have a part to play, not as judges but as educational and scientific advisers to the teachers and the schools. It is not only social aspects which need attention but also psychological factors: the level of thinking of the pupils, their motivation and other psychological matters. The teacher's awareness of these issues is manifest in his behaviour vis à vis his pupils and can be made explicit through observations and discussions.

Optimism was also evident about the potential of science teaching associations and science centres as foci for the improvement of integrated science teaching. G. Ghaznawi raised an issue which had been relatively neglected during the conference. The place of mathematics. His experience with the National Science Centre of Afghanistan led him to recommend that mathematicians should share the centre with scientists. This would be cheaper than setting up a separate centre and would also enhance integration and unity. Mathematics is an essential tool for the scientist and many of the processes studied by scientists could qualify as mathematics in their own right. The qualities which new mathematics and new science courses try to develop in children and students have much in common and more is to be gained than lost by bringing the two areas of study together.

Ghaznawi wanted to see science supervisors and inspectors working from the science centre. They themselves would receive intensive in-service education at the centre (he suggested about six weeks each year) and would then go out into the schools, well primed to help teachers with respect to content, methodology, new equipment and desirable innovations in all areas. If the number of contact schools could be kept fairly small the teachers would enter into a progressive and productive relationship with the supervisor who should call regularly and be available on request for consultation and advice. Problems which the supervisor could not solve himself could be answered after discussion at the centre, either with the permanent staff or with teachers there on courses. If no answer was forthcoming the teacher initiating the enquiry would at least know that he was not alone. The insecurity and doubt of many a lone teacher are substantial and inimical to adventurous innovation.

B. Pitre was disturbed by the cut-and-dried nature of the diagram produced by group Wc. He wanted due acknowledgement of the individual and of variations from a common pattern. Science teachers' associations, inspectors and senior science teachers will be subject to many influences not delineated in the diagram. Social pressures, personal relationships and personal ambitions will all distort the idealised picture which has been drawn. Pitre would have welcomed closer attention to the differences between developed and developing countries. He agreed that there are common problems but the difficulties experienced by, say, a science teaching association in a sparsely populated, poor country, make its potential quite different from that of an association in a rich, urban community.

P. Richmond felt that international conferences could work to identify the *differences* between nations in the way they can tackle their problems and to recognise in a constructive way that not all things are possible or even desirable in every country. This issue itself could stimulate productive discussion within an association or as part of a course on the introduction of integrated science in school.

The papers presented and the subsequent discussion indicated clearly that the days of a teacher shutting himself up in a classroom or laboratory and teaching his specialist subject untroubled by the outside world, are gone. Administrators, inspectors, headteachers, colleagues, parents and even students and children all feel they have points of view which should be acknowledged by the teacher. The expectations of society and of the consumers of education vary widely but no longer can they be ignored.

The trainers of integrated science teachers have a heavy responsibility to ensure that those they work with are ready not only to take their places in schools as they are but to strive to make them better. There is a growing army of evaluators inside and outside the school waiting to see if they have succeeded.

Part 4

The Social Significance of Science Education

1. A Unesco expert and his assistant discuss the design of an electric bell.
(Photo: Unesco)

2. A University lecturer and an elementary school teacher discuss the design of a windmill
(Photo: Alan Haywood)

Plate 4. Ideas for Teachers of Integrated Science.

3. Teaching Science through games

4. Discussing materials for teaching integrated science.

5. Computer simulated experiments
(Photos: FUSE)

THE SOCIAL SIGNIFICANCE OF THE TEACHING OF SCIENCE AND MATHEMATICS IN THE COMMONWEALTH

Maurice Goldsmith,
Guinness Awards for Science Teachers, London.

I see integrated science teaching however defined, whether as an integration of science subjects, or an integration of science with other non-science subjects, as historically inevitable. Nothing less will do now at a time when the old rules no longer apply, and when uncertainity in social and political senses is our daily companion. Science itself for many years past has been one: the great unifying principles of this century have shown that the divisions into physics, chemistry, and biology are man-made, dictated by temporary historical needs. Only in the classroom do they linger on, linked to a deadly examination system which poisons the wells of creativity.

It is fashionable today to discuss the limits of growth and development of physical resources. But there is another limit to growth which is not mentioned. It arises from the fact that we have exhausted the intellectual wealth that was contained in the curricula and institutional forms which were established a hundred years ago. To seek to continue to mine them will bring only disaster. All richness has gone. Fortunately the human mind, unlike fossil resources, can renew itself and reveal new riches, but this needs a new orientation. An attempt to formulate this for science and mathematics was made from 29 March to 2 April 1973 at a Conference of Commonwealth Countries on the theme of 'The Social Significance of the Teaching of Science and Mathematics'. Forty people from these countries were invited to meet on the Mona campus of the University of the West Indies at Kingston, Jamaica.

The basic document which was sent to all participants in Kingston began as follows:

> "Experimental Science was a latecomer to the school curriculum, and it has continued to occupy its separate place, sometimes neglected and usually unrelated to other studies. Even the different branches of science are often taught independently of one another, and without regard to the pupil's development of the required mathematical principles. In spite of efforts made during the last two decades to give scientific subjects and mathematics their role in education, they have remained in many instances self-contained formal studies throwing little light on current social and technogical developments. The observational (social or behavioural) sciences are even more recent additions to school programmes. There has, therefore, been little opportunity to relate scientific insights and innovations to changes in social patterns, and to the wellbeing of human societies.
>
> The effects of this deficiency are particularly evident in developing countries, and those with too low a level of production for a rapidly increasing population. It seems clear that science and technology can only give their full benefits to mankind if they come to be seen during the years of education as profoundly important factors in social development. Hence, it is necessary to include in the sciences the study of the social as well as the material environment. In this Symposium we can take as the field of our discussions the natural sciences, mathematics, and the social sciences. A broad proposal of this kind, associating the experimental sciences, technology and mathematics with social and economic structures, must raise new and important issues. Those topics that seem of the most immediate concern have been selected for the six sessions available for discussions".

The six topics were: Science, Technology, and Society; the Inter-relation of the Natural

Sciences, Technology, Mathematics, and the Social Sciences; the Interdependence of Science Learning and the Environment; the Economic Factors Influencing Science and Mathematics Education; Objectives for the Curriculum (in two parts: dealing with structure, methods and content, and with relevance and self-reliance); and finally, the Preparation of Science and Mathematics Teachers.

The Conference was organised by the Guinness Awards for Science and Mathematics Teachers and the six topics reflected themes which have arisen as the Guinness Awards Scheme has grown and developed over the past ten years. Teachers and teachers-in-training from the United Kingdom and overseas have been invited to develop and report upon sound and imaginative methods of teaching science and certificates and cash prizes totalling £1,500 are awarded annually to the best entries. The Awards Scheme has spanned a decade which began with an emphasis on skills and knowledge and has proceeded through many changes, some ephemeral, some long lasting, to an awareness of the social significance of science and mathematics education. In Jamaica we asked two major questions. What can education through science and mathematics do *for* society? And what can education through science and mathematics do *to* society? We have used the term education *through* science and mathematics quite deliberately as we believe that the most valuable contribution which science and mathematics education can make to the development of individuals and of society, lies in the central position of these subject areas in providing relevant experiences in the context of general education. While also contributing a fund of useful knowledge, it is the contributions made via the inquiring, problem solving, activity centred experiences, that characterize the major value of modern science and mathematics education. To the knowledge and skills now developed by such methods we would wish to add the development of desirable social attitudes which will ensure that these skills are subsequently used in beneficial ways both for the individual and for society as a whole. This applies not just in formal employment, but should also be seen as appropriate to family and community life.

While greater efforts to give science education some technological orientation have begun recently, the social sciences have made little impression on school work. Major issues of our time such as pollution and population seldom find a place in the classroom. Clearly this is a field in which much development work is required and the gathering of relevant information is of considerable importance. It is important that the educational process should include from the earliest years of schooling some investigation of family, industrial, agricultural and social life, and the use that is made of scientific and technical material. If such inquiries are made the starting points of more systematic study it is doubtful whether the separate branches of science and mathematics can or should be studied in depth, at least until the upper part of the secondary school is reached.

So far as the teacher is concerned, we agreed that the quality of education through science and mathematics will depend to a very large extent on the quality of the teaching. In the changing society in which we live the present patterns of teacher education are becoming increasingly integrated and should be reassessed. It is essential that the education of our teachers should contain an adequate preparation for the teaching of science in an integrated fashion, taking into account the social needs of the community. Alternative models of teacher education should be studied and tried. The theme in developing such models must be the close linking of the school, the community and the teacher education institution.

On the curriculum, we said:

> "We believe that the development of any new curriculum in science and mathematics should be the responsibility of the individual region or area concerned. In this way,

social and psychological factors will not be overlooked. Foreign materials should be examined very critically for ideas appropriate to local situations. It is unlikely that detailed materials from other countries will be applicable other than for reference and resource purposes".

An analysis of both traditional curricula and some of the new schemes produced in the last decade suggests that a process of evolution has been occuring in our analysis of curriculum requirements and structure. Traditional courses emphasized the acquisition of knowledge. Many first generation and second generation 'new' courses also placed considerable emphasis on knowledge but of a more structured kind and at the same time developed a series of aims and objectives as criteria for course construction rather than relying solely on the inherent logic of a given subject. We are now clearly entering a third phase in the process whereby to the requirements of knowledge and behavioural aims and objectives has been added the desirability of developing appropriate attitudes to science, mathematics, technology and society. Examples of these third generation 'new' curricula are the Schools Council Integrated Science Project (SCISP) (United Kingdom) and the Australian Science Education Project (ASEP) . This new phase has particular significance for further developments at the secondary level and we believe that the new balance being achieved between knowledge, skills and attitudes is a considerable improvement on previous patterns.

It follows from an analysis of desirable new trends in teacher education that the teacher in future will have a different role from hitherto. This will be relevant to the curriculum development situation also. We believe that the individual teachers must be more closely involved in curriculum processes. Professional teacher associations form alternative foci for teacher based curriculum work and are also worthy of support.

Finally I want to return to attitudes and values. Science should bring to us self-knowledge enough for us to perceive what the mystic always held: namely, that the key to wellbeing lies more in the design of our aspirations than in devising means to satisfy them. To use Sir Julian Huxley's phrase science and mathematics teachers shape the minds that contain the possibilities of the earth's immense future. We can realize more and more of these possibilities if we increase our knowledge and our love.

THE SOCIAL RESPONSIBILITY OF SCIENTISTS AND THE RECIPROCAL RESPONSIBILITY OF SOCIETY

John Maddox, Editor, 'Environment and Change', London

The social responsibility of science has in the past few years been an exceedingly fashionable subject, and in my view there is a danger that it will become too fashionable. For the truth is that science has much in common with other branches of intellectual life – philosophy, economics and literature, for example.

Scientists are primarily concerned to understand the world, or the universe, in which we live, just as economists are concerned to understand the workings of the social institutions which have grown up in the past few centuries and just as writers are concerned that literature should in some sense become an increasingly perceptive tool in understanding human beings. Within all these fields, there are standards of excellence or elegance to which the practitioners aspire, each field is also a potentially powerful source of the improvement of society at large.

Applied science, which includes both engineering and medicine, is the technology much respected in the 1950s and now much feared. Just as scientists help with the construction of nuclear reactors or supersonic aircraft, so economists help governments – not always successfully – to control the pace of industrial growth and – the denials of litterateurs notwithstanding – writers have a powerful influence on the spread of ideas through the modern world and on the stimulation of ordinary people's consciousness.

So why is it that ordinary people and scientists are much more exercised about the social responsibility of science than about the social responsibility of economics or of literature? It is true, of course, that a new development in technology, a supersonic transport, for example, may be potentially beneficial and potentially harmful, but the same is true of innovations in other fields. Keynesian economics is a good example. Keynes may have made possible the New Deal, now at least acknowledged to have been a liberal development, but Keynesian economics has also made it easier for the advanced nations of the world to insulate themselves from what might be held to be the legitimate economic interests of the developing world by making possible the more accurate construction of protective tariffs, probably one of the most powerful restraints on economic and social development in the developing world. And if people raise the question of whether scientists are acting with social responsibility when they assist in the development of, say, laser bombs of the kind now being used in Vietnam, why do they not also ask whether the army of economists which has helped the Administration to support the war in South East Asia without running into insupportable economic difficulties are not similarly to be castigated?

In reality, both the scientists and the economists are helping to implement political decisions from which, in this case, many people dissent (and from which I would dissent if I had a vote in the USA). I am not especially wishing to argue that it is unfair to single out the scientist for blame but, rather, to suggest that these issues are inherently political. If people dissent from the Administration's policy in South-East Asia or from the way in which advanced countries shelter behind protective tariffs and thus keep the underdeveloped world from developing as it might (as I wish they would), the remedy must be found not in persuading either scientists or economists to refuse to work for governments pursuing distasteful policies but in the political process itself.

The political institutions which the democracies have painfully developed in the past three centuries, imperfect and in need of improvement though they may be, will be irreparably damaged if we pretend that the responsibility of scientists has been discharged if they elect not to work with projects of which they disapprove. In other words, those who argue that scientists should not help to develop laser bombs and who go no further are not merely deluding themselves in thinking that the Vietnam war would go away if it were not for technology but are helping to undermine political institutions which, for all their imperfections, are the most conspicuous differences between our societies and barbarism.

From this it seems to me to follow that there is no great virtue in what may be called the negative approach to social responsibility – the argument that people with professional skills, scientific or otherwise, should exercise their social responsibility by declining to work on projects or with enterprises from whose objectives they dissent.

To be sure, all professional people habitually exercise the right to work on projects they enjoy and, by extension, decline – or should decline – to do work that is abhorrent to them, and that is as it should be. Intellectuals march with their heads, not on their stomachs – or should be so inclined. What this implies is that people with particular skills can exert a profound influence on the way in which governments function by their willingness to work towards government objectives or by their unwillingness. The point I am trying to make is that an individual who declines to work on laser bombs, but who finds a job for himself in the computer industry instead, is exercising a considerable influence on the extent to which a government can pursue a malevolent objective. This does of course raise the question of scientists actually employed by governments who are, at least in principle, likely to be directed to work on projects they dislike. Perhaps the scientific community, instead of talking of the social responsibility of science so much, should devote some effort to making sure that people in such a position are in practice more free to make value judgments than they are at present – by which I mean that they should be less insecure about job opportunities, transferability of pension rights and things like that.

It must also be acknowledged, where technology is concerned, that there are a great many situations in which it is literally impossible, at the outset of a development programme, to make anything like an accurate assessment of the balance that should be struck in the advantages of some innovation and its potential disadvantages. In the past few decades, there have been several vivid examples – nuclear weapons, thalidomide and so on – of how in the development of technology it is often easier to anticipate the benefits than the unwanted side effects. But surely this is yet another argument for saying that what modern society needs is still more vigorous experiment and a still wiser political process for deciding which innovations should be exploited and which left on the drawing board or the development workshop. It seems to me to have been madness on the part of the United States Congress to have cancelled the programme for developing a supersonic aircraft when much of the money had already been spent, when it would have been possible to use an experimental aircraft for answering still hypothetical questions whether supersonic aircraft will damage the environment insupportably.

All this boils down to saying that the most urgent task for scientists exercised by the need for social responsibility in science is that they should, as individuals, become engaged in the political process. There is much that they could accomplish. Especially in the United States, Congress is eager to listen to what critics of the Administration say – and I wish that more level-headed scientists had been occupied in this kind of work in recent years. The present convention, among scientists, appears to be that the radicals should speak out loudly but that more sober people, members of government committees usually, should remain silent. This is the reason why the extremists of the environmental movement have managed to stampede governments and even parliaments into unwise legislation – the 1975 Auto Emissions Standards are not merely impractical but uneconomic, for example. What is it that makes the scientific community so vulnerable to overstatement?

Detachment from politics is an explanation but no excuse. It is also fair to say that the academic community is less idealistic than it wishes its students to believe. The members of government committees on minor subjects who feel themselves thereby constrained from any kind of criticism are legion. Within the academic community, prestige – and tenure – counts for far too much. Paradoxically, I think it would be possible for the profession of science so to organise itself that its influence on public affairs was at once more radical and more constructive (a synonym for conservative) than it is at present.

Perhaps the reason why science has been so much maligned in the past decade is that the public has sensed this ambivalence within the scientific community. The potential social responsibility of science is diluted by a quite understandable wish for an easy life. But it seems to me that scientists are not solely responsible for this unhappy circumstance. In the past few years, the community at large has been ungenerous to science, hoping that it will be an influence for change but trying to make sure that all the changes will be palatable and that the cost will not be great. The truth is, however, that science has done more than any other branch of intellectual life, in the past century, to undermine received doctrine and has done so entirely legitimately. Which of us can tell what will be the outcome of the majestic description of the universe which Einstein and his followers provided half a century ago? Which of us can tell where molecular biology will end? But do we not all know that the consequences will in their own way be as great as the recognition that the Earth is round, not flat? And does not the taxpayer have a responsibility to make sure that this enterprise is not wantonly brought to a stop not just for lack of funds but for lack of understanding?

CONTRIBUTIONS OF COURSES AND EXPERIENCES OTHER THAN THOSE IN SCIENCE AND SCIENCE EDUCATION TO THE EDUCATION OF THE TEACHER OF INTEGRATED SCIENCE

Report of Working Group Wd.

Chairman: Jean D. Grambs, University of Maryland, U.S.A.
Rapporteur: Arthur W. Torrie, UNESCO, Bangkok, Thailand.

1.0 Terms of Reference

1.1 To consider the training of teachers of integrated science in the overall context of teacher education and identify existing courses other than those specifically in science and science education which have a contribution to make to the training of teachers of integrated science.

1.2 To develop a core of experiences, activities and course-work which all teachers-in-training need to experience, and to highlight the contribution of such courses to the training of the teacher of integrated science.

1.3 To specify with respect to the total education system, the responsibilities of integrated science teachers and those responsible for training them.

2.0 Background

2.1 Traditionally, the training of teachers in teachers' colleges and other places of higher education has been rooted in the separate science disciplines. These have been taught with some reference to mathematics, but beyond this, with little reference to any other subject in the college curriculum. From time to time, some colleges have attempted to correlate the work of one department with that of another but this has not always been practicable or successful. The teachers emerging from these various kinds of educational institutions have usually had a background of one or two science subjects such as chemistry, physics or biology and some knowledge of how to teach them in school classrooms. Mostly, they have lacked an appreciation of the role played by science education in the intellectual growth of the child and additionally, the relevance of the subject they are teaching to the needs of the society in which the children eventually will live and work.

2.2 During the last decade, curriculum developers in many science education projects throughout the world have become increasingly conscious of the social, economic and psychological implications which their science programmes have for the children and for society. As a result, more attention has been paid to the psychological aspects of the learning process in young children and a natural extension of this concern has been a greater awareness of the need to teach science as an integrated part of the total curriculum. With the advent of integrated science these problems have been compounded by the previous restricted training of teachers for the new job in hand. Ideally, teachers of integrated science need to have considerable knowledge of all the science disciplines, if they are to be able to teach the subject effectively. Additionally, they need to know about the role of science teaching with respect to the total curriculum as well as the social, economic and other needs of society.

2.3 The first ICSU Conference on Integrated Science held at Varna in 1968 dealt mainly with the general philosophy of integrated science teaching and highlighted the need for attention to be focussed on the advantages of teaching an integrated or combined science to young children compared with the separate disciplines. In the early 1970's UNESCO sponsored a number of meetings, seminars and workshops on integrated science teaching. The first was in

Manila, Philippines, in August 1970. The next was in Suva, Fiji, and was associated with the wider concept of curriculum development. The third was in Ibadan, Nigeria, In September – October 1971, and the fourth was in Penang, Malaysia, in August 1972.

2.4 The Manila Workshop identified a basic need to extend the training of teachers of integrated science into a much wider sphere. Part III of the Workshop Report entitled 'An Approach to Integrated Teaching in Asia' pp. 14/15 reads:

> "The complex of inter-related social, psychological and economic factors which influence learning must be taken into consideration in the design of new science curricula in Asian countries. Conversely, the introduction of science teaching into the lower grades of schools in Asian countries can, if the teaching is appropriately carried out, have a profound influence on the child's attitude to his total environment. The dynamic relationship between socio-cultural influences, on the one hand and the learning of science, on the other, is an area which merits intensive study in Asian countries. Such knowledge as already exists must be given careful consideration by those concerned with science curriculum planning and design".

This perhaps, is the first time that a meeting on curriculum development in the integrated science field has acknowledged in its report that knowledge and attitudes outside the conventional field of science teacher education is relevant to the training of science teachers.

3.0 Assumptions

The delegates agreed that certain assumptions were necessary before they could proceed with discussions which would enable them to come to grips with the problems in hand.

3.1 The social problems of today are inextricably interwoven with scientific and technological implications and further, as the extent of science and technology increases so will the social implications becoming greater.

3.2 The advancement of both science and technology creates new social conditions which may impose negative and positive conditions on human society.

3.3 Accordingly, the citizen will be increasingly called upon to weigh carefully the social questions which have arisen out of technological developments impinging on the local, national and international community.

3.4 Without a treatment of scientific concepts in relation to their social and historical contexts, science teaching will tend to be inadequate. A treatment of the social and historical aspects will be increasingly important in the education of future science teachers.

3.5 As in the past, tomorrow's science teacher will tend to teach as he himself has been taught. In recognizing that limitation, the pre-service education of teachers of integrated science must exemplify those concepts, attitudes and skills which are to be part of the educational experience of the current generation of youth.

3.6 The curricula and teaching methodologies at the college or university level, should be revised to reflect the social context of science if wider perspectives in society are to be realized.

3.7 Accordingly, with reference to 3.6 above, the material of instruction available in teachers' colleges, secondary, or elementary schools, must be consistent in inter-relating the social needs of society with scientific knowledge, attitudes and understandings.

4.0 Major Issues

Major issues were identified in order that there should be some framework for further discussion.

4.1 The first major issue is to decide what area of content outside the science disciplines should be included in teacher education programmes on a first priority basis. Should it be philosophy and history, or perhaps the humanities and arts? Should it be applied technology or the social and behavioural sciences? Or are there other content areas which are not only relevant but important in the education of science teachers? For example, is a knowledge of the world's religions relevant and important to the future teacher of integrated science in a world that metaphorically speaking, is becoming smaller and smaller?

4.2 Can traditional courses which are at present provided for the education of science teachers, be modified so as to present scientific knowledge, attitudes and skills related to the needs of human society? If so, are additional courses beyond the science requirements really necessary?

4.3 Is traditional course work sufficient to improve the general education of the science teacher? Or should he be involved in a series of experiences exceeding the demands of the classroom such as in industry, community development, field assignments, social welfare and other activities which may widen his horizons?

4.4 What are the minimal social and cultural understandings necessary for the scientist and science-literate citizen which will enable both to make intelligent decisions about the application of science and its technology to everyday situations? An example of this problem is the failure of the proponents of the 'Green Revolution' to foresee the cultural and social implications and its consequent limitations.

4.5 What instructional materials will have to be generated in order to support the teaching of an integrated science course, which adequately treats the social and cultural implications of scientific concepts, principles and technological applications?

4.6 What cross-cultural understandings are necessary to enable the teacher of integrated science to interpret more adequately the teaching of science in relationship to its social setting? More importantly, how can this best be achieved?

4.7 With reference to classroom teaching, what are the methodological implications of presenting science in the social context?

4.8 With reference to all of the preceding issues, is it likely that the objectivity of both the scientist and science educator is likely to be threatened in any way by immersion in the social setting?

5.0 Generalizations Arising from Discussion

The basic problems which confronted this group in its deliberations was the lack of information about the kinds of programmes which would best develop the future teacher of integrated science education. To complicate the issue, the concept of integrated science teaching is a new one and definitions of it vary considerably. It was also soon apparent that the needs of science teacher education in developed and developing countries are likely to be different. This dichotomy of interests was difficult to resolve because the bases for teacher education in the two kinds of societies are obviously quite different.

In considering the major assumptions and issues put forward by the chairman, the delegates in plenary and group sessions formulated a number of generalizations which are likely to govern the education of teachers of integrated science.

5.1 The first was that science education takes place within society and therefore should be an integral part of that society.

5.2 The culture of each particular nation determines to some extent, not only what science content may be selected, but how this should be related to the needs of the community, both local and national.

5.3 The third generalization concerns the socio-economic background of the society for which the training of teachers of integrated science is being devised. It is obvious that the needs of an urban industrial society must be quite different from those of a society which is essentially agricultural and rural.

5.4 The fourth generalization concerns that of religion. When this was brought forward for discussion, it was first of all thought to be irrelevant until interested delegates began to cite examples of religious conflicts within nations and between nations which must have some bearing on the education of science teachers at the tertiary level.

5.5 The fifth generalization is that ideally, the education of teachers for integrated science should be a continuous process and that attention must be given to creating more opportunities for teachers to keep abreast of the changing times during their teaching careers.

5.6 The professional competence of the teacher of integrated science is based on knowledge, attitudes and skills, which should be acquired from a wide background of activities gained at the university or teachers' college and subsequently during the teacher's career.

6.0 Experiences Useful to a Teacher of Integrated Science

Delegates in the group identified a number of experiences which are likely to be useful in the training of a teacher of integrated science.

6.1 The participation of the student-teacher in programmes which include students of the natural sciences, social sciences and the humanities is thought to be most helpful, particularly where there is opportunity for informal discussions in seminar groups.

6.2 Student-teacher participation in courses where faculty teaching reflects an interdisciplinary approach is also thought to be most useful experience.

6.3 The directed exposure of students to the attitudes and problems perceived by local communities and studied as integrating themes linked to relevant aspects of their science education studies.

6.4 Participation in organized programmes which emphasize the techniques of non-verbal teaching are also thought to be of considerable use in the education of the young student-teacher.

6.5 Training in the making of value judgements and the clarification of issues concerning such judgements in fields related to the application of science and technology to society.

6.6 Early encounters with children of a variety of ages and social levels, are thought to be important in giving student-teachers a better understanding of the intellectual growth and social attitudes of the children they will eventually teach.

6.7 An exposure to specialized aspects of other disciplines which will make the student a better teacher of integrated science is emphasized. It cannot be denied that some background of mathematics, statistics, dramatic and fine arts, sociology and psychology will create better science teachers.

6.8 Encounters with the aged, and with cultures and sub-cultures other than their own are thought to be important in most societies.

6.9 In developing countries, it is recommended that student-teachers be exposed to developmental planning which would make them familiar with national goals and the part that science education might play in achieving these goals. Knowledge of national resources, potential resources and trade policies would also make the future teacher aware of the role of science and technology in developing these resources.

6.10 Above all, it cannot be over-emphasized that the future teacher of integrated science needs to be given a good knowledge and understanding of his environment, both social and physical, while he is a college student.

7.0 An Operation Model

Several models were constructed in an attempt to design one which in a simple way would illustrate how the contributions of courses and experiences other than those in science education could increase the competencies of the teacher of integrated science. It was agreed that the competencies needed by the teacher of integrated science in the modern world go far beyond the boundaries of science education. This teacher requires additional knowledge, attitudes and skills to be able to pass on to his pupils the ability to interpret for themselves the role of science and technology during a period of rapid social and technological change.

7.1 The final model shown in Figure 1 indicates how the competencies of the teacher of integrated science are acquired through courses and experiences at college. The disciplines in the outer rim of the model contribute in varying degrees to the experience of the student, depending on how relevant the course is to his future teaching career.

7.2 The interdisciplinary courses and experiences of the next sector of the model are those which are most pertinent to his becoming a more effective teacher. Many of these courses and experiences have already been identified in section 6.0 of this chapter. It is emphasized that imaginative and innovative interdisciplinary courses should be devised to expand the knowledge attitudes and skills needed by the teacher of integrated science.

7.3 It is expected that continuous communication and feed-back between student-teachers and faculty would bring about modifications in the progressive development of graduate and undergraduate programmes. Furthermore, the model shows an all-important feed-back which should be obtained from pupils in classrooms staffed by teachers who have been trained through such interdisciplinary programmes. The development of innovative teacher-education programmes such as the model suggests should be assisted by special interest groups in the community where relevant.

8.0 Examples of Programmes

There are relatively few programmes in operation which contribute to the education of teachers of integrated science through courses and experiences outside the science education field. Samples have been chosen from different parts of the world so as to indicate how various educational institutions have devised such programmes to suit their needs.

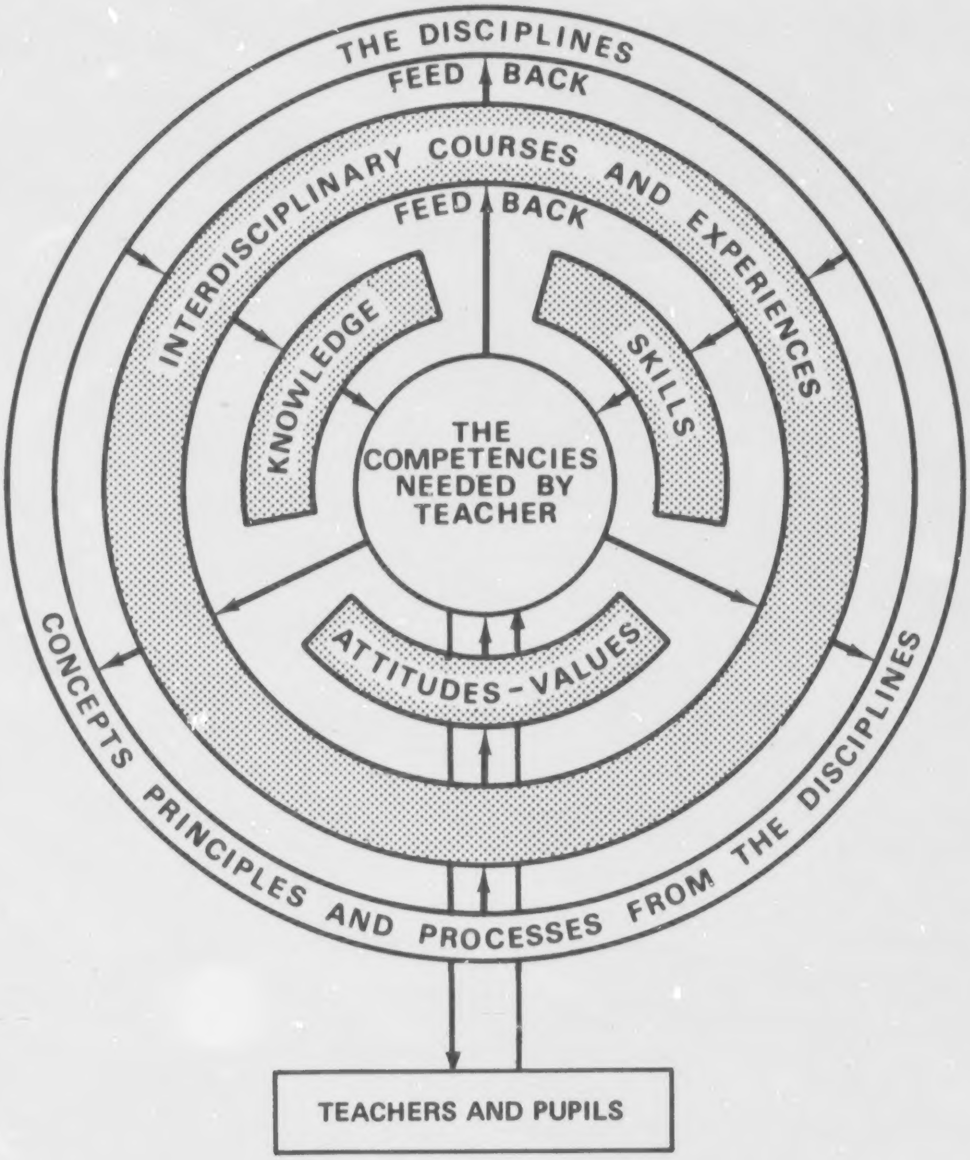
THE DISCIPLINES
FEED BACK
INTERDISCIPLINARY COURSES AND EXPERIENCES
FEED BACK
KNOWLEDGE
SKILLS
THE COMPETENCIES NEEDED BY TEACHER
ATTITUDES - VALUES
CONCEPTS PRINCIPLES AND PROCESSES FROM THE DISCIPLINES
TEACHERS AND PUPILS

Figure 1. **The Model. Contributors to the Competence of an Integrated Science Teacher.**

8.1 *University of Wisconsin, Green Bay Campus*

At the Green Bay Campus, all degree programmes are organized around environmental problems rather than around traditional disciplines. Each student selects a particular theme from the biological, physical, social, or cultural aspects of the environment for study in depth. Competence within a disciplinary and/or professional area, is developed with special concern for applications to the student's chosen environmental problem.

The development of social responsibility as well as technical expertise is emphasized through a wide range of problem-orientated courses which cross disciplinary lines. The student is also exposed to a variety of experiences which give an opportunity to apply this knowledge in real-life situations outside of the classroom.

8.2 *University of Ibadan, Nigeria*

'The Meaning of Science' – this is an ancillary course for the first year Bachelor of Education degree (B.Ed.) and for the Post-Graduate Diploma in Education (PGDE). It is available for both science and non-science students.

The course examines the logical foundations and mechanics of the scientific enterprise in-so-far as these are identifiable. It attempts to show the history of science as a related function of the total life of society and science itself as a human activity with socio-economic implications. Furthermore, it attempts to show the implications of the history and philosophy of science to the African.

Thus, the course deals with the history, philosophy, sociology and psychology of science. The principle objective is to enable students to understand the implications of science and perhaps to build a bridge across the 'two cultures' which are evident in African societies. It is also hoped that the course will give the science teacher a deeper insight into his discipline and help him to put it in a more balanced perspective. It is felt that this is increasingly important to science teachers in a world in which sciences and technology touches every aspect of human life.

8.3 *Monash University, Melbourne. Australia*

Monash University offers three interesting science education courses as extensions to its post-graduate diploma of education. These courses are available to graduates who have already completed a degree in either science or mathematics. They are good examples of the kind of wider spectrum education which delegates feel is necessary for the teacher of integrated science.

(i) *Science and mathematics curriculum theory*

This subject is offered for a semester session of three hours per week. During the course students are given the opportunity of advancing their understanding of cognitive disciplines. They also consider the objectives of science and mathematics curricula and the philosophical and psychological contributions to science curriculum theory.

(ii) *Science and mathematics: social and philosophical aspects*

This course also consists of a semester of three hours per week. The study includes the interaction between science/mathematics education and society as well as the social and technological questions that arise from this interaction.

The structure of science and mathematics is also studied. Topics considered, include confirmation and refutation of hypotheses, laws, models, theories, translation rules and operational definitions.

(iii) *Science and mathematics curriculum materials development*

The same amount of time is available as for the first two courses. In this subject, students are expected to develop, try-out and evaluate instructional materials. Lectures are given on test construction and relevant aspects of research design. The students work either individually or in small groups, and the materials produced are tried out in active classroom situations.

8.4 *University of British Columbia*

At the University of British Columbia, the Science Education Department offers a programme for under-graduates and graduates in elementary, secondary and tertiary education where the emphasis is on experimental learning based on the environment. In this programme, the development of integrated science is being pursued where the integrating factor is environmental experience.

Courses are offered for the non-science orientated elementary teacher which develop within the integrated construction, the unity and diversity of science and the thought processes of science. A course in Environmental Education is offered which develops the integration component of science education emerging from experiences in the environment. A Science Education course at the senior level considers, as part of its offering, the strategies and techniques of developing a curriculum for an integrated programme and the pedagogy that supports such a programme. Finally, there is a graduate course on the Preparation and Development of Curriculum and Curricular Materials which considers the problems of integration.

In this way, alongside the more traditionally orientated science programme, an alternative is being presented which prepares a teacher capable of implementing integrated studies in environmental education if it is the teacher's wish and the controlling authority permits.

9.0 Considerations and Recommendations for Implementation

Members of the working group have listed what they consider to be the most important recommendations which will bring about the implementation in universities and colleges of the kind of educational programmes which they think to be desirable for the education of teachers of integrated science.

9.1 *Official Support*

It is important that officials in Education Bureaux, Ministries of Education and their staff be informed of the needs for the training of teachers of integrated science so that their support may be obtained.

9.2 Adequate financial provision from the Central Educational Authority should be requested in order that the planning for new programmes may be expedited and that such programmes may thereby gain official sanction.

9.3 *Strategies for New Programmes*

Strategies need to be developed in order to establish new training programmes for the education of teachers of integrated science. These involve:

(i) initiating innovative pilot projects and experimental programmes in universities and colleges;

(ii) developing administrative structures to facilitate interdisciplinary co-operation including planning, course development, field experiences and related activities. The budgetary needs of these programmes may require consultant advice;

(iii) the dissemination of new materials should include the description of model programmes, evaluative data, course materials and field guides. Dissemination may logically take place by organizing local, regional, national and international conferences, seminars or workshops which have a specific focus on this area of teacher education;

(iv) procedures for informing and involving academic staff of colleges and universities are essential if the model is to succeed. These teacher educators are key personnel in implementing new programmes and may themselves need to be reorientated towards the new outlooks.

9.4 *Cultural and Religious Considerations*

(i) Programmes and models should reflect cultural differences and be organized with awareness of different religious interests and attitudes and will therefore carry from one locale to another.

(ii) Efforts should be made to see that any of the programmes which are borrowed from other countries are adapted in such a way that they reflect the true cultural attitude of the country of their adoption.

(iii) Likewise, teachers should be made aware of different attitudes that are to be found within different religions, especially where the teaching of integrated science is concerned. They should be given a background of understanding for the handling of some of the more delicate issues where science was often confronted religious attitudes.

DISCUSSION AND COMMENT RELATING TO PLENARY SESSIONS ON THE SOCIAL SIGNIFICANCE OF SCIENCE AND THE RELATION OF SCIENCE TO OTHER SUBJECTS

Much of the discussion after the lectures of Maddox and of Goldsmith centred on the extent to which substantial and explicit reference to social issues should be made in science courses. There were other doubts as to whether any social references that are made should be optimistic or pessimistic. This very issue highlighted a difficulty many felt. Is social science scientific enough to be included in a school science course? It is commonly accepted that a hierarchy of precision exists ranging between physics and social science, with chemistry, biology, geology, geography and other sciences scattered in between. The interplay of theory and experiment in physics or chemistry is evident. A consensus of opinion among physical scientists is relatively easy to achieve and results are highly reproducible. The probability that the major laws of physics will ever be upset is very low indeed and there are great generalisations which none would dispute and few would wish to see omitted from a science course. This is less true of biology or geography and scarcely true at all in the social sciences where there are no great laws and the agreed generalizations tend to be trivial. The way of presenting material to a class may influence their opinions and there are few controlled experiments which can be performed to rectify subjective bias. Nor is there a body of agreed opinion against which personal views can be tested. Some thought this to be a strength of social science as an educational medium. Scientific knowledge is highly structured and its logical, sequential nature has made it all too easy for teachers to present it as blocks of information to be encompassed. It has been too easy to learn it from a textbook. The injection of social commentary into school science would bring all the benefits of an increasing social awareness of its effects and, in addition, would demonstrate that not all science is certainty.

J. Layman wondered whether scientists could effectively adopt a social science role and wondered whether they should even try to become economists or politicians, aiming to change behaviours outside the fields in which they have been trained. Such a course of action might be unacceptable to the authorities of many countries, it could be ineffective or, at worst, harmful both to the pupils and to their communities. Maddox however reiterated his belief that scientists can make an informed contribution on many issues and should do so. Perhaps the field has been left open too long to those without scientific competence. Scientific training is not a disqualification for participation in the affairs of society. But the question of how far teachers should go in sensitizing their pupils to the issues was not pursued in depth, neither did we discuss the part teacher trainers must play. Nevertheless teachers, whatever their position, have to make choices of courses, content, emphasis and teaching style. Each of these choices has social implications yet it is rare for this to be pointed out in training courses. Some 'principles of education' or 'educational philosophy' courses raise such issues but philosophers qualified to advise on the consequences of choosing a particular science course are rarer than scientists able to comment sensibily on politics or philosophy!

To those who felt pessimistic about the future of the world, Maddox pointed out that it is social issues rather than scientific ones which offer the greatest threat to our future. It may be true that ill-effects of Roman forestry methods can still be seen in the Mediterranean but it was social not technological issues which caused the collapse of the Roman Empire. Technical problems and the side effects of technology are more easily contained than social ones. He was critical of the Club of Rome's 'Limits of Growth', questioning the assumptions, the equations and the extrapolation. He saw future sources of material under the sea and in recycling processes.

G. Ramsey was concerned that in future too much attention might be paid to systems and too little to people. There is a huge inertia in social systems which can act for or against an individual. It is essential to ensure that changes by legislation or economic pressures do good not harm to the people most concerned. Attempts at violent changes of policy can cause hardship in the short-term and fail in the long term because of the capacity of most real systems to assimilate change to past practice – a process which has become increasingly evident as substantial changes in school science teaching have been called for. As we train our teachers we should bear this in mind. An appreciation on the part of teacher training staff of the social and psychological constraints acting on attempts at innovation is essential. Perhaps a training course for integrated science teachers needs a quite different kind of social bias from the one we might expect the teachers to adopt when they get into their schools.

Chandrakant Dikshit drew attention to the importance of local issues and strongly recommended that teacher trainers explore the possibility of using cultural traditions to reinforce their programmes. World and national issues make no impact on many teachers and children but all live in a *local* community. A teacher can make use of customs, practices and even myths where these support his aims. He should recognise them, use them where he can and allow for them where they pull against his purposes. P. Richmond recalled the well known observation that many children in developing countries will state, in school, most definitely, that all drinking water must be filtered and boiled – and then go home to drink untreated water from the stream. He described a parallel situation in developed countries where children learn that all electrical apparatus must be earthed – and then cheerfully use non-earthed equipment at home. Examples are legion of unacknowledged mis-match between precept in school and practice at home both in concrete terms as above and in less obvious ways such as attitude and opinion. Teacher trainers must know whether curiosity and the asking of questions are valued behaviours in their community or whether they are subject to disapproval. The behaviour of a science teacher who appreciates the social influences may be quite different from one who seeks only to implement a given course of study, come what may.

Religious questions are usually considered to be outside the scope of science teaching. Yet Dikshit noted that in many schools in India children every morning speak a Sanskrit prayer:

> "Teacher is the Lord that creates
> Teacher is the Lord that sustains
> Teacher is the Lord that weeds out (destroys)".

Religious views are deep-seated and teacher trainers preparing entrants to schools where such a prayer starts each day cannot unthinkingly recommend that later the teacher should join in with the children, acknowledge ignorance and offer only an unobtrusive lead. He may decide still to recommend such behaviours but only after very serious consideration of the social (religious) factors in operation. Dikshit offered a solution to the dilemma he had highlighted. When a teacher remembers that Para-Brahma is a universal god, he can be prepared to relinquish his dominant position and act less obtrusively. The teacher is less an omnipotent autocrat than a 'diffuse god' showing his power by his deeds. But such an approach could necessitate a massive change in a man's whole approach to his children, his job and his life, and a comparable change on the part of the pupils. Psychological, social, cultural and religious influences are widespread and deep-rooted. No change in education should be attempted without acknowledging their presence and one task of teacher trainers is to alert students to their existence and to offer guides as to how to evaluate and justify in social terms changes judged to be desirable and possible.

Teachers so prepared will, by virtue of their extended thinking, have become better prepared to see the relation between science and society and better prepared to ensure that the science courses their children experience, are related to the needs and desires of the community.

Part 5

A Working Bibliography of Integrated Science Education

Children from Tamagawa Gakuen primary school in Japan.
(Photo: Unesco)

Plate 5. This volume has discussed the education of teachers. These photographs are included as reminders of our prime concern: The children and their work.

A BIBLIOGRAPHY ON TOPICS RELATED TO THE EDUCATION OF TEACHERS FOR INTEGRATED SCIENCE

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Introduction

This bibliography was originally prepared to provide background material for participants in the ICSU Conference on the Training of Teachers for Integrated Science. It contains articles which present a rationale for combining and interweaving the disciplines, as well as articles stressing the social implications of science and technology. Also included are the documents and articles which describe many of the major integrated projects, courses, and units of work currently being developed and taught. Other references pertain directly to teacher preparation and in-service training for integrated science. Entries in the bibliography are not classified according to the type of document but are arranged alphabetically by author or title within each section. Whenever possible annotations are included.

Part I of the bibliography includes articles in the literature of Eastern European countries. Journals from the following countries are represented: Bulgaria, Czechoslovakia, Democratic German Republic, Hungary, Yugoslavia, Poland, Romania and the Soviet Union. The bibliography covers literature appearing during the years 1969 to 1972 inclusive.

Part II is limited to articles and documents written in English and pertaining to integrated science in countries outside the United States and Eastern Europe. Many of the articles have been suggested as pertinent by the directors of the integrated projects appearing in the *Eighth Report of the International Clearinghouse on Science and Mathematics Curricular Developments 1972.* Where possible, these articles have been obtained and annotated.

Part III includes only documents that have originated in the United States of America and is limited to items which are reasonably available through libraries and/or the Educational Resources Information Center (ERIC) system. Assistance in obtaining any of the documents in Part III is offered by the Center for Unified Science Education, Ohio State University, Columbus, Ohio, 43221, USA.

BIBLIOGRAPHY OF ARTICLES FROM EASTERN EUROPEAN SOURCES

Altmann, A., 'Didactive Principles in Biological Education'. *Statni pedagogicke nakladatelstvi:* Praha, 1971, p. 66. Czechoslovakia.

The author deals with the didactic principles of the relations between subjects involved in biological education. Consideration is given to the bases of biological knowledge including geology, chemistry, physics and eventually mathematics. The significance of these subjects to biology teachers is stressed. Inter-subject relations *within* biology and *between* different subjects are discussed.

Altmann, A., 'Natural Objects in Biological and Geological Education'. *Statni pedagogicke nakladatelstvi:* Praha, 1972, p. 136. Czechoslovakia.

Describes the production, maintenance and utilization of instructional aids. The author pays some attention to the problem of the inter-subject relations.

Arpai, J., 'The Role of Natural Sciences in General Education'. *Jednotne skola,* Vol. 21, No. 6, 1969, pp. 501–509. Czechoslovakia.

The author proceeds from the requirements posed by the scientific and technological revolution, showing the importance of a comprehensive integrated approach to the imparting of information in schools. The student should first and foremost be familiar with the ways of thinking and not only the matter pertinent to a given scientific subject. As an example, the author adduces some basic biological categories, stressing the importance of the intellectual development of the student.

Babadzajan, S., Monachov, V. M., 'Interdisciplinary Relations in Mathematics and Natural Sciences in Optional Courses'. *Sovetskaja Pedagogika,* Vol. 24, No. 10, 1970, pp. 36–42. U.S.S.R.

The authors discuss which levels of preparation lend themselves to the introduction of interdisciplinary relations. The article focuses on relations between mathematics and physics. Mathematical introduction to vectorial algebra and its uses in different fields of physics and chemistry (vectorial planes, linear programming, vectorial theory of co-valency ties in chemistry, selected chapters from astronomy, etc.) are given as examples.

Batkova, E., 'Increased Efficiency in Teaching and Problems of Interdisciplinary Relations'. *Profesionalno obrazovanije,* Vol. 20, No. 1, 1972, pp. 15–19. Bulgaria.

The article discusses different forms of interdisciplinary relations. Apart from general analysis, the article offers practical topics demonstrating these forms on actual teaching material. The proportion of hours involving both theoretical and practical instruction (efficiency) is also discussed.

Berger, A. and Ohst, H., 'Co-ordination of Biology and Chemistry Lessons'. *Chem. Sch.,* Vol. 18, 1971, No. 5, p. 224. German Democratic Republic.

The co-ordination of physiological, biological and chemical themes in the GDR is considered and examples are given of topics in which necessary knowledge and skills are acquired before or after they are needed in a particular subject.

Bojkovska, A., 'Intersubject Relations Between Chemistry and Geography'. *Prir. Vedy Sk.*, Vol. 23, No. 8, 1971/1972, p. 298. Czechoslovakia.

It gives reasons for attempting the co-ordination of chemistry and geography lessons – illustrated by examples.

Borisenko, N. F., 'The Nature of Interdisciplinary Relations'. *Sovetskaja pedagogika*, Vol. 35, 1971, No. 11, pp. 24–31. U.S.S.R.

The study of interdisciplinary relations takes into account relations existing between different scientific disciplines. Examples of co-operation between disciplines are listed (physics, chemistry, biology, archeology, etc.). The respective relations within each specialized subject are illustrated graphically.

Borisov, M., Karabasev, N., Matev, V., Stanev, S., 'The Implementation of Inter-Relations Between Physics and Other Natural Sciences in General Education'. *Narodna Prosveta*, Vol. 26, 1970, pp. 3–14. Bulgaria.

The article contains part of the paper read at the international congress in Varna in 1968. Attention is drawn to relations between physics, biology and chemistry. Different forms of integrated teaching are discussed in detail.

Borsanyi, J., 'Concentration with Physics in Systematic Revision of Lessons in the 3rd Grade of Gymnasium'. *Kem. Tanit.*, Vol. 8, 1969, No. 2, p. 51. Hungary.

Concentrated on co-operation of chemistry teacher and biology, physics and mathematics teachers. It shows the possibilities of co-operation in classes and themes.

Chytilova, M., 'The Role of Physics in Polytechnical Education at General Secondary School Level'. *Matematika a fyzika ve skole*, Vol. 2, No. 9, 1971–72, pp. 548–553. Czechoslovakia.

The article discusses the relations between physics and technology and the application of the polytechnical principles, both in scope and form of instruction, in the teaching of physics. The assumption of inter-relations is demonstrated by a number of concrete examples.

Constantinescu, E. and Filipescu, V., 'Principles of Working Out the Content of Education in the Ten-Year School'. *Revista de Pedagogie*, February 1969, Vol. 18, pp. 55–63. Romania.

The curriculum in the ten year school was elaborated taking into account the role of the ten year school in the general system of education. In working out the draft curriculum and the syllabuses attention was paid to the principles of pedagogical theory and practice. Underlying these principles is the correlation of subjects in each form and throughout the entire ten years, which brings more efficiency into education.

Creteanu, F. and Popescu, C., 'The Relationship Between Technology and the Scientific Subjects'. *Revista de Pedagogie*, Vol. 21, No. 5, May 1972, pp. 28–31. Romania.

The authors elucidate the advantages of co-operation between the teachers engaged in teaching sciences and the rest of the teaching staff. Such methodological co-operation and exchange of experiences eliminate any biased approach that may impede the educational process.

Csengeri, E. and Voiculescu, I. C., 'The Drafting of Syllabuses for Biology Classes at Grammar School Level'. *Revista de Pedagogie,* Vol. 18, No. 7–8, 1969, pp. 165–168. Romania.

The author stresses that at grammar school level (lycée) the teaching of natural sciences must take into account the integration of knowledge in a form that leads to an understanding of matter and the basic processes in living beings. A multilevel approach to studying nature is proposed to achieve this integration.

Dobrev, Z., 'Nature Study Syllabus'. *Nacalno Obrazovanije,* Vol. 12, No. 2, 1972, pp. 23–30. Bulgaria.

Problems concerning instruction in organic and inorganic nature study are discussed with practical examples of suitable teaching methods. Pupils in the fourth form of primary schools are taught to recognize differences between objects, minerals and animals. This was envisaged as the first stage of interdisciplinary relations.

Dolejsi, V., 'Remarks on the Presentation of the Subject: Plant-Production'. *Zemedelska skole,* Vol. 20, No. 1, September 1969, pp. 7–9. Czechoslovakia.

Possibilities of the inter-subject relations among plant production and other subjects.

Eichler, E., 'Notes on the Article: A Unified Approach to Teaching Mathematics and Natural Sciences'. *Physik in der Schule,* Vol. 7, No. 6, 1969, pp. 282–283. German Democratic Republic.

The contribution contains notes on problems of teaching natural sciences. Some typical examples are analysed. This article is a follow-up of another contribution appearing in *Physik in der Schule.*

Filinov, G., 'Notes on Laboratory Work in Nature Study Classes – 4th Form'. *Nacalno Obrazovanije,* Vol. 9, No. 2, 1969, pp. 19–25. Bulgaria.

The class is divided into groups of three, working on nature study projects. Using laboratory equipment for chemistry and physics (test-tube support, asbestos grid, compasses, magnet) the groups were given guidance in discovering through tests and experiments the different properties of matter. The author stresses the fact that this method proved stimulating as it furthered an independent approach.

Fedorova, V. N., 'Didactic Utilization of Relations Among the Branches of Natural Science in School'. *Biol. Chem.,* Vol. 14, No. 3, 1970, p. 13. Bulgaria.

Acceleration of development of different branches of science raises the question of integration and differentiation of branches of natural science as the subjects of a general secondary school. Inter-subject relation can be dealt with from many points of view, e.g. informative: facts, concepts, theories or chronological: preceding, parallel and perspective subjects. As a result of analysis of both the points of view the following order of subjects is found to be the best: physics, chemistry, biology. The realization of chronological and inter-subjects relation is illustrated by working out the concept 'substance' in the 5th, 6th and 7th grades of the general secondary school.

Filipescu, V., 'Laboratories – Efficient Ways of Organizing the Teaching Process'. *Revista de Pedagogie,* March 1972, Vol. 21, No. 3, pp. 13–20. Romania.

The article emphasizes the importance of a scientific organization of the teaching process in schools today and discusses three relevant problems: the need of teaching in laboratories, the standard of equipment in the laboratory, which should correspond to the specific requirements of teacher and class and the subject taught.

Fischer, J., 'On the Common Language of Mathematics and Physicists'. *Czechoslovak Journal of Physics,* Section A, Vol. 19, No. 3, 1969, pp. 327–328. Czechoslovakia.

The article gives several examples of the use of some concepts in mathematics and physics. The author demonstrates the thought processes and procedures in mathematics and physics and arrives at the conclusion that a dictionary of mathematical and physical terms is desirable.

Gancev, I., 'Mental Ability Test'. *Matematika,* 1972, Vol. 11, No. 3, pp. 26–28. Bulgaria.

Ten questions are presented in the article testing ability and knowledge in the following subjects: mathematics, physics, chemistry, logic. Readers must select one of the five alternative answers provided. Instructions are given for working out the answers.
Note: The test is designed for 14–17 year age group.

Georgiev, D., 'International Congress on Integrated Teaching in Natural Sciences'. *Matematika i fizika,* Vol. 12, No. 1, pp. 62–68. Bulgaria.

The Congress discussed the following topics: (1) aims and methods of integrated teaching, (2) models of integrated teaching, (3) definition and scope of integrated teaching, (4) mathematics and integration, and (5) teacher training for integrated teaching.

Gersie, J., 'Teaching Natural Sciences at Secondary Schools – Scope and Textbook Compilation'. *Jednotne skola,* 1971, Vol. 23, No. 2, pp. 109–117. Czechoslovakia.

The article discusses the didactic principles of teaching natural sciences and the syllabus. The presentation of subject matter and the importance of interdisciplinary relations (mathematics, physics, chemistry, biology, etc.) are dealt with in detail. Notes on textbook writing conclude the article.

Harazin, J., 'Electrolysis of Aqueous Solutions of Inorganic Matter'. *Fizyka w szkole,* 1969, Vol. 15, No. 3, pp. 16–25. Poland.

The article deals with electrolysis as one of the possible spheres for integrated teaching of physics and chemistry. The author offers a detailed description of how the concepts can be taught and gives the relevant chemical equations. Examples and the calculation of electrode potentials are given.

Horz, H., 'Natural Bases of Socialist World Outlook – Consequences and Possibilities of Instruction'. *Cem. Sch.,* Vol. 19, No. 3, 1972, p. 97. German Democratic Republic

A general essay on the importance of natural science, especially physics for education in the world outlook. The world outlook is explained as a system of answers to the questions about the origin of the world and the sources of knowledge, about man in the world, about the purpose of his existence, and about the character of social progress. Examples in relation

to materialism and dialectic consequences for instruction – the role of experiment (as, 'an objective analyzer of reality and a criterion of verity') is considered to be particularly important.

Kesler, M., 'Physical and Chemical Processes'. *Pedagoski rad,* Vol. 25, No. 3–4, 1970, pp. 173–183. Yugoslavia.

The article describes physical and chemical tests to which rope and synthetic fibres are submitted. Pupils handle microscopes and chemical compounds in the laboratory during experiments. The second series of tests are tests for water softening. Attention is paid during the experiments to effects of pollution and impurities and their solubility.

Klevenskij, Ju. N., 'An Introduction to New Findings in Astronomy'. *Fizika v skole,* Vol. 31, No. 4, 1971, pp. 83–84. U.S.S.R.

The author shows that close relations exist between astronomy and physics. The course under consideration involved an account of the physical aspects of stars, their movement in terms of the Doppler principle; problems of radioastonomy (rotation of Mercury) were included.

Kokorin, N. A., 'Structure and Subject Matter in New Courses for the Sixth Form'. *Fizika v skole,* Vol. 29, No. 5, 1969, pp. 55–59. U.S.S.R.

The new teaching programme adheres to the principle that pupils of this age are taught about physical phenomena demonstrated on the composition of matter. The article discusses the most elementary compounds showing how knowledge of physics could be of help in understanding the chemical qualities of matter.

Kazmierski, J., 'Co-operation of Chemist and Biologist in a Basic School'. *Chem. Szk.*, Vol. 16, No. 4, 1970, p. 194. Poland.

Gives reasons for the need of integration of school programmes of chemistry and biology. Examples of the themes concerned are given. Attention is called to the necessity of the use of universal nomenclature and interpretation of phenomena. One of the advantages of co-operation of chemist and biologist is, among others, the intelligibility of interpretation of concepts, more permanent knowledge and economy as far as time is concerned.

Lange, W., Wettstadt, G., 'Institute for Mathematics, Natural Sciences and Polytechnical Education – Experience and Results of New Methods'. *Pedagogische Forschung,* 1971, Vol. 12, No. 3/4, pp. 108–114. German Democratic Republic.

The article reviews the whole of the Institute drawing attention to: (1) polytechnic education; (2) mathematics and the natural sciences. A project is described where the following subjects are co-ordinated: chemistry, mathematics, physics, biology and astronomy.

Lechner, H., 'The Scientific Education of Pupils in the General Polytechnical School With Special Regard to the Intermediate Level'. *Physik in der Schule,* Vol. 8, 1970, No. 10, pp. 460–461. (Excerpts from a dissertation – Humboldt University). German Democratic Republic.

The problem is approached from the point of view of vocational schools at secondary level. The conclusion offered stresses the need for an integrated approach to natural sciences.

Levitan, E. P., 'Some Ideas about Scientific Investigation Tasks in the Sphere of Methodology of Instruction in Astronomy in Secondary Schools'. *Astronomie in der Schule*, 1969, Vol. 6, No. 4, pp. 98–102. German Democratic Republic.

The article is concerned with the elaboration of a system for the instruction of concepts of astronomy in syllabuses at secondary schools. The survey shows that pupils in lower grades start learning the basic definitions of astronomy in mathematics, physics, chemistry and biology.

Lieberg, K., 'Studies of Energy in Science Lessons'. *Physik in der Schule*, 1971, Vol. 9, No. 5, pp. 229–231. German Democratic Republic.

The article presents a summary of a dissertation thesis concerned with the acquisition of concepts, laws and theories in the field of physics, chemistry, biology, astronomy and technology, offering a comprehensive solution of problems relevant to integrated teaching of natural sciences in the above mentioned fields. The article presents a detailed list of tasks and priorities essential in the construction of new curricula. The discussion is exemplified by the concept of energy and the laws of conservation of energy.

Livescu, J., 'The University and Interdisciplinary Research'. *Revista de pedagogie*, Vol. 20, No. 1, 1971, pp. 14–16. Romania.

The author stresses the fact that the contributions of the conference indicate a contemporary approach, one that takes into account the educational consequences of present day developments in sciences and the search for criteria determining their structure in terms of development in the socialist society. At the university level the interdisciplinary approach underlies the general orientation of scientific research.

Loskareva, N. A., 'Literature on Inter-subject Relation'. *Chim. Sk.*, Vol. 33, No. 2, p. 82, 1969. U.S.S.R.

The list of work is divided into following groups: (1) the problem work, (2) the role of inter-subject relation in forming the scientific world outlook of pupils, (3) the content of inter-subject relation and methods of its realization, (4) the role of inter-subject relation in the choice of teaching methods and forming of skills, (5) inter-subject relation in extra-curricular activities, (6) the role of inter-subject relation with regard to the culture of speaking and writing.

Mader, O., 'On the Position and the Function of Astronomy within the System of Natural Sciences at the Secondary School'. *Astronomie in der Schule*, Vol. 6, No. 5, 1969, pp. 124–128. German Democratic Republic.

The article discusses basic problems posed by the introduction of new syllabuses in secondary schools in the GDR. Astronomy was introduced in 1971/1972. The need for co-ordination arises in a number of subjects including mathematics and physics. The author stresses the importance of astronomy being included in an integrated syllabus, and discusses a number of problems of a didactic – methodological nature.

Mincenkov, E. E., 'Employ Your Pupils' Knowledge of Physics in Chemistry Lessons'. *Chim. Sk.*, Vol. 33, No. 4, 1969, pp. 45. U.S.S.R.

It stresses the importance and it gives examples of the inter-subject relation of chemistry and physics.

Mincenkov, E. E., 'Facts of Chemistry Applied to the Teaching of Physics in the Ninth Year'. *Fizika v skole,* 1971, Vol. 31, No. 6, pp. 30–32. U.S.S.R.

Thermal and electric phenomena are taught in the ninth year. The pupils are familiar with Avogadro's hypothesis and the uses of Mendel's periodic system which help them determine physical quantities such as weight, density, etc. Chemical bonds offer a rich source of instruction.

Mincenkov, E. E., 'Interdisciplinary Relations and the Structure of Syllabuses in Chemistry and Physics'. *Sovetskaja pedagogika,* Vol. 35, 1971, No. 11, pp. 32–40. U.S.S.R.

The realization of interdisciplinary relations presupposes a well balanced course. The matrix approach is used to illustrate these relations. Individual points are discussed in these terms.

Mraz, V., 'The Relation Between General and Specialised Teaching in Vocational Schools'. *Pedagogika,* Vol. 19, 1969, No. 4, pp. 616–621. Czechoslovakia.

The article discusses the negative aspects of overloading the primary school pupil and the encyclopedic type of teaching in these schools. A number of concrete examples of the advantages arising from interdisciplinary relations and the importance of building up a well-planned system of imparting information are stressed. The different functions of teaching material are discussed. The article concludes by emphasizing the need of giving more prominence to subjects of general education in the syllabus. A historical comparison is presented.

Neuzil, J., 'Co-ordination of Natural Science Lessons in a General Secondary School and the Place of Chemistry in Curricula for a Gymnasium'. *Materials of Studies for Teaching Chemistry; Miscellany of Specialized Group for Teaching Chemistry CSSCH.* Ceske Budejovice, PeF 1969, p. 133. Czechoslovakia.

A brief suggestion for modification of curricula and school programmes that are being prepared by gymnasia (secondary schools), exemplified by co-ordination of practical training, and comparison of curricula.

Nicolescu, M., 'Mathematics and Co-operation Between Subjects. *Revista de pedagogie,* 1971, Vol. 26, No. 1, pp. 10–13. Romania.

The author considers that interdisciplinary research characterizes all trends in science to date. It is the natural outcome of the long process of parallel development in different subjects. Mathematics has replaced Latin and religion as the binding factor of all science.

Pav, T., 'Integration Trends in Teaching Natural Sciences'. *Pokroky MFA,* Vol. 14, No. 6, 1969, pp. 279–282. Czechoslovakia.

The article presents facts on a new teaching programme, tried out in Scotland (Scottish Education Department 1964–1968). The course comprises physics, chemistry and biology. Work in the class is facilitated by work sheets differentiated according to the age of the pupil. This pilot course was launched in 25 secondary schools and the article provides a comprehensive survey of this course.

Petrova, P., 'Effecting Interdisciplinary Relations in Teaching'. *Professional-no obrazovanije* Vol. 18, No. 3, 1970, pp. 26–27. Bulgaria.

The article stresses that teachers using interdisciplinary methods in teaching must have a thorough theoretical grounding in general subjects, non-applied technical fields and in special subjects. The importance of this approach in physics, mathematics and chemistry is underlined. The author gives examples from electrical engineering.

Redaktion, 'Astronomielehrer schreiben über Erfahrungen aus der Unterrichtsarbeit'. *Astronomie in der Schule,* Vol. 7, No. 1, 1970, p. 92. German Democratic Republic.

The editorial board requested teachers of astronomy to send in a list of basic problems concerning the introduction of new syllabuses. The topics include many centering on an integrated teaching plan; such as the role and function of astronomy in teaching natural science and the significance of astronomy in the specialized training of students.

Redecker, G., 'A Unified Approach to the Teaching of Mathematics and Natural Sciences'. *Physik in der Schule,* Vol. 7, 1969, No. 3, pp. 129–135. German Democratic Republic.

Teachers of mathematics and natural sciences in a Berlin secondary school (Andreas Oberschule) elaborated a draft programme for the integration of teaching material in mathematics and natural sciences. Apart from a general survey and a list of individual topics the article also gives a series of examples. The Editorial Board invites other teachers of secondary schools to send in their suggestions concerning the draft and in particular give the experience gathered during its application.

Reznikov, L. I., 'Combined Courses of Physics and Mathematics'. *Fizika v skole,* 1969, Vol. 29, No. 5, pp. 55–59. U.S.S.R.

Teaching material for new types of courses in mathematics and physics have been elaborated in recent years. The article discusses in detail interdisciplinary relations in mathematics and physics. A number of concrete examples and a detailed exposition of the type and scope of these courses are given.

Rossa, E., 'Chemistry as a Part of Education in Mathematics and Natural Science'. *Chem. Sch.,* Vol. 16, No. 11, p. 365, 1969. German Democratic Republic.

Three main functions are stressed: (1) to emphasize theories, laws and reasoning important for deeper penetration of science, production and social events; (2) to show a wide range of application in the use of utilised methods and proçesses of scientific, technical and creative activities; (3) to seek the co-operation of mathematics natural science and other branches of knowledge.

Stan, T., 'Humanities and the Teaching of Physics and Chemistry'. *Revista de Pedagogie,* December 1969, Vol. 18, No. 12, pp. 31–38. Romania.

The author quotes the results of research undertaken in schools during 1968–1969. In physics and chemistry lessons he attempted to record the following: the ability to define, expound, anticipate and work out definite problems. Examples and results of this research are given.

Sawicki, M., 'Integration of Science in Nature Study'. *Nowa szkola,* 1970, No. 1, pp. 19–21, Vol. 19. Poland.

The article reviews the approach to this problem in individual countries, with particular reference to Western countries. The relevant programmes concern biochemistry, biophysics, physical chemistry etc. The first phase of the programmes comprises algebraical techniques, exercises in logic and new language forms. The second phase involves practical integration of natural science disciplines.

Schmidt, V., 'The Scientific and Technological Revolution, School and Development'. *Pedagoski rad,* 1971, Vol. 26, No. 7–8, pp. 284–300. Yugoslavia.

The article stresses that mere accumulation of knowledge is no longer feasible and advocates integrated teaching. The author points out that grammar schools have no integrated plan for subjects like mathematics and logic, biology and physics. The same situation exists in chemistry, physiology and psychology. The author emphasized the need for a more systematic approach to teaching and the necessity to co-ordinate teaching programmes in physics, chemistry and biology at secondary schools. The article also discusses similar problems at university level.

Schwarzova, J., 'Co-operation with Research-Institutes Yields Profit for Teaching as Well as for Production'. *Zemedelska skola,* 20/6/: pp. 88–89. Czechoslovakia.

Inter-subject relations between chemistry and plant-production in experiments with plant-nutrition.

Stanev, St., 'Report on the International Congress on Integrated Teaching in Natural Sciences'. *Matamatika i fizika,* Vol. 12, No. 1, pp. 63–64. Bulgaria.

The article gives a brief account of the congress with notes on each contribution. The author discusses some of the models of integrated teaching already in use, listing topical research problems highlighted by the congress.

Szewczuk, W., 'The Psychological Nature of the Integration of Teaching'. *Nowa szkola,* Vol. 19, No. 4, 1970, pp. 27–28. Poland.

The article stresses the psychological aspects of this type of teaching (e.g. systematicity of knowledge acquired). Examples in theoretical analysis are drawn from biology, astronomy and geography.

'The International Congress on Integrated Teaching'. *Fizika v skole,* Vol. 29, No. 1, 1969, pp. 105–108. U.S.S.R.

A. N. Kolgomorov and G. G. Maslova review the proceedings of the Congress on Integrated Teaching at the session of the Academy of Pedagogical Sciences (U.S.S.R.). The Congress focused on questions concerning the teaching of mathematics and natural sciences in schools.

Timosenko, M. Z., 'Interdisciplinary Relations in Physics and Physical Geography'. *Fizika v skole,* Vol. 31, No. 1, 1971, pp. 56–57. U.S.S.R.

The article lists a variety of ways and means demonstrating how the relations between these two subjects can be brought within the reach of the pupil. Physical geography provides suitable material that can be made use of in physics and alternately, physics facilitates the

explanation of some natural phenomena. The article gives a set of questions and topics for the sixth and the seventh year.

Trajer, J., 'The Second National Conference on Polytechnical Education'. *Pedagogika,* Vol. 22, No. 2, 1972, pp. 231–234. Czechoslovakia.

Reviewing the results of the conference, the author lists the main contributions and gives a brief summary of each. The conference stressed the importance of interdisciplinary relations in polytechnical education for mathematics, physics, natural sciences, geology, chemistry etc. A polytechnical approach is also applied in history, civics and literature.

Vachek, J., 'Co-ordination of Instruction in Mathematics and Physics in Secondary Schools'. *Pokroky MFA,* Vol. 14, No. 3, 1969, pp. 144–148. Czechoslovakia.

The article discusses the problems which the co-ordination of mathematics and physics present in secondary schools. Outward and inner co-ordination is distinguished and individual factors in both categories are discussed. Though the two subjects differ, co-ordination is, in actual fact, feasible. The advantage of one teacher handling both subjects is particularly stressed.

Vachek, J., 'Some Aspects of Co-ordinated Teaching in Mathematics and Physics'. *Matematika a fyzika ve skole,* Vol. 2, 1971–72, No. 9, pp. 539–548. Czechoslovakia.

The author focuses attention on the internal and external problems of co-ordination in mathematics and physics. Examples analyzed in detail are used to demonstrate relations between physics and chemistry, physics and biology etc. Formal methods of mathematics in relation to teaching physics are discussed in detail.

Vaideanu, G., 'Interdisciplinary Research and its Utilization in Systems of Education'. *Revista de pedagogie,* Vol. 20, 1971, No. 1, pp. 28–34. Romania.

Three major problems concerning interdisciplinary research in education are discussed:

1. (a) Promotion of the interdisciplinary approach through collaboration between pedagogy and other sciences.
   (b) Application of this approach at all stages of research.
2. Prerequisities for integrated interdisciplinary research.
3. Application of the results of the conference 'Interdisciplinary Research in Education'.

Vaideanu, G., 'Scientific Management and Technological Innovations in Education'. *Revista de Pedagogie,* March 1972, Vol. 21, No. 3, pp. 3–12. Romania.

The author defines innovation and technology of education. A number of suggestions and contributions issued by CRIE (Centre for Educational Research and Innovation) are analyzed. The second part of the article discusses the prerequisites for the new education policy in Romania in the following areas of concern: research, decision making, education.

Vajda, D., 'Some Aspects of the Contemporary Approach to Teaching'. *Jednotna skole',* Vol. 22, No. 6, 1970, pp. 493–508. Czechoslovakia.

The article gives a detailed survey of the many problems of contemporary teaching. The historical determination of teaching and learning, the position of facts in a scientific and

didactic system etc. Interdisciplinary relations are discussed in detail. The article also gives attention to problems concerning the extent of information imparted during the teaching process.

Vajda, D., 'Towards a Conception of World Outlook in the Teaching of Natural Sciences'. *Matematika a fyzika ve skole,* Vol. 1, No. 2, pp. 90–94. Czechoslovakia.

The article is concerned with topical questions affecting education geared towards a scientific outlook in natural sciences. The author's discussion takes into account both the historical and contemporary facts and the relations between science and religion.

Vasiljev, Ju. V., 'Interdisciplinary Relations in Teaching at the Pedagogical Institute' (Teacher Training for Nursery Schools). *Sovetska pedagogika,* Vol. 35, No. 12, 1971, pp. 68–79. Soviet Union.

One of the most important problems in training nursery school teachers concerns the realization of interdisciplinary relations. The author distinguishes four different stages. The system of interdisciplinary relations is illustrated graphically and the advantages and disadvantages are discussed.

Vystavel, B., 'An Integrated Approach to Teaching Natural Sciences'. *Matematika a fyzika ve skole,* Vol. 2, No. 9, 1971–72, pp. 568–570. Czechoslovakia.

The article reports on integrated projects in teaching, defines the main trends and lists the relevant literature.

Zabara, V. F., 'Inter-subject Relation in the Process of Chemistry Lessons'. *Chim. Sk.* 33, No. 3, p. 38, 1969. U.S.S.R.

Examples of the relation of chemistry to biology, physics and geography.

Zavadil, D., 'About Chemistry in the Agricultural Training Institutions'. *Zemedelska skola,* Vol. 19, No. 10, pp. 145–148. Czechoslovakia.

Proposal for a programme of chemistry with examples of inter-subject relations.

BIBLIOGRAPHY OF ARTICLES WRITTEN IN ENGLISH AND PUBLISHED IN COUNTRIES OUTSIDE THE UNITED STATES AND EASTERN EUROPE

Alonso, Marcel, 'Integration of Science and Education in Latin America', in P. Gillon and H. Gillon (Eds.), *Science and Education in Developing States,* Proceedings of the Fifth Rehovot Conference. London: Praeger Publishers, 1971, pp. 53–62.

Presents reasons for the neglect of science in the curricula of developing countries and suggests that a knowledge of science is needed by those who would advance the technology of the country and also by the politicians and government workers responsible for decisions of national interest. Refers to science as, 'not only a tool for technological development but, as a basic cultural element in everyday life'. Stresses the need for both a regional and a national program to improve science education.

Bingham, E. W. and Bingham, K. C., 'An Experiment in the Teaching of General Science'. *Science Notes and News,* July 1972, pp. 28–29. Jamaica.

Discusses a first attempt to adapt the discovery approach in a first form general science class. The program follows the lines suggested by Nuffield Combined Science.

Birch, Peter, and Melville Harris, 'The Environmental Studies Approach'. *Dialogue,* No. 6, August 1970, pp. 7–9. United Kingdom.

Description and philosophy of the Environmental Studies Project for 5–13 year olds. Environmental studies is described as an Educational approach available to a teacher based upon direct experience of the environment. The approach leads naturally to an overflow of study into many aspects of the curriculum – especially in the fields of language and mathematics. Specialist materials are available for teachers only.

Bishop, Mark, 'Science in Future'. *The Australian Science Teachers Journal,* Vol. 9, November 1963, pp. 23–29. Australia.

Recommends the integration of science with English, history, and language study. Suggests that science touches upon, depends upon and contributes to an understanding of them all. Attention is called to the advantages of a team approach in curriculum development. Notes that we must begin now to prepare leaders for 1990–2000 and curricular change takes time.

Blum, A., 'Horticultural Curriculum as Part of Science Education and Prevocational Guidance in Junior Secondary Schools'. *Proc. 18th International Horticultural Congress,* Vol. 1, Tel Aviv, 1970.

Blum, A., 'Science Teaching in Developing Societies; Some Psycho-Social Determinants'. *New Trends in Integrated Science Teaching,* Vol. 1, UNESCO, Paris, 1971.

Considers the question of 'adoption or adaptation' as a problem of science teaching in developing countries. Makes a plea for combining the experimental approach of modern science teaching with subject matter content taken from the students' intimate environment. Mentions the agro-biological units developed in Israel as part of the integration of science teaching with agriculture.

Booth, N., 'Middle School Science'. *Trends in Education,* Vol. 24, October 1971, pp. 13–16. United Kingdom.

The author recommends establishing a rational core of learnings to occupy one-half to three-quarters of the middle school student's science time. Such a core might focus on the three themes: matter, energy, and life.

Case, Sheila M., 'The Language Barrier in Science Teaching'. *Teacher Education in New Countries,* Vol. 9, No. 1, May 1968, pp. 15–26. Malawi.

Report is part of a preliminary survey of the problems encountered when using English as a medium for teaching science to pupils whose mother-tongue is a Bantu language. Survey of pupils' written work revealed that errors fell into seven main groups: direct translation, pronunciation, deficiency of scientific words in Bantu languages, prepositions, articles, subjects of verbs, and problem words whose meaning can only be learned by experience. Each of the above groups of errors is discussed.

Clark, R., 'The Case for an Integrated Tertiary Science Course.' *Science Education News,* August 1968. Australia.

An attempt is made to arrive at a statement of what integration is. The philosophy of, and the case for, integrated science courses is discussed. Past efforts to formulate integrated science courses are considered and suggestions are offered on how future courses should be constructed.

Clarke, J. D. and Herington, G. N., 'Rural Science for Secondary Schools'. *Teacher Education in New Countries,* Vol. 1, 1960. Malawi.

Two-thirds of the article is devoted to detailed suggestions on how to teach a three-year syllabus that combines nature study, hygiene, agriculture and simple science in a course that could be the core of the whole curriculum of a rural school. Shows how rural science can be related to many subjects.

Congress of the Integration of Science Teaching, General Report on Congress, Droujba, Bulgarie, September 11–19, 1968. Paris: CIES, p. 74.

Report of meeting aimed at studying the possible development of courses in integrated science which would organize the teaching of the subject as a coherent whole. Attention directed toward the secondary level. Discusses 'complete integration' which consists of joining several subjects into a single course in which the concepts of science are presented through a unified approach, and 'co-ordination' which entails a carefully planned collaboration between the various disciplines. Suggests guidelines for the training of teachers. Discusses special aspects of integration of science in developing countries.

Connell, W. F., 'Science for the Non-Scientist'. *The Australian Science Teachers Journal,* Vol. 9, November 1963, pp. 17–20. Australia.

Discusses the critical role of science at the secondary level where the gulf between science majors and non-science majors develops and intensifies. Presents some basic principles for designing a science program to bridge the gap. The author suggests that such a program should not consist of separate subjects, but a series of appropriate topics which should deal with modern rather than classical science. It needs to be of practical and daily significance and should examine the lives and contributions of modern men of science.

'Curriculum Development'. *The Journal of the Ghana Association of Science Teachers,* Vol. 11, June 1970, pp. 42–45. Ghana.

Presents a proposed structure for O-Level science education stressing an integrated approach. Recommends that general principles of science should be applied to such areas as agriculture and technology, although these applied subjects should not be taught as such within the course. A general description of the aims for secondary school science education in Ghana is accompanied by a reformulation of those aims in terms of nine skills and attitudes which the student should be able to demonstrate at the end of his science course.

'Curriculum Development Notes – Appraisal of STAN Integrated Science'. *STAN Journal,* May 1970. Nigeria.

Driscoll, D. R., 'Some Recent Changes in Science Teacher Education'. *The Australian Science Teachers Journal,* Vol. 18, June 1972, pp. 21–28. Australia.

Examines current professional preparation for intending secondary science teachers and introduces the concept of concurrent courses in education where learning of science is integrated with teaching of science courses. A general description is given of the Nuffield Science Teacher Education Project (S.T.E.P.).

Elstgeest, Joseph, 'Ask the Ant Lion: The Growth of an African Primary Science Unit'. *A Report of an African Education Program,* Newton, Mass.: Educational Development Center, 1967, pp. 13–20.

Descriptive article about one of the A.P.S.P. units which introduces children to personal observation, experimentation, devising experiments and evaluating the outcome, collecting data and interpreting them.

Elwell, J. J., 'Preparing Teachers for Work in Combined Science with Children Aged about 11 to 13 Years'. *IPN-Symposium 1970,* über Forschung und Entwicklung Naturwissenschaftlicher Curricula, pp. 163–168.

This article describes many of the important considerations to be faced when introducing a program such as Combined Science into the school setting. First, it is necessary to 'look carefully at the scheme to see what changes are envisaged in the pattern of behaviour of the children in the school. The behaviours which the developers of the scheme have in mind may well conflict with that generally expected in the school and unless this is recognized and a solution devised, tensions may be set up not only in the children but also amongst the teaching staff'. Next the role of the head teacher in establishing and ensuring an appropriate environment for the scheme to be attempted is discussed. Finally the teacher training described for this scheme involves maximum and direct exposure to the actual Combined Science materials – the tests, the apparatus, and other requirements.

Elwell, M. J., 'Nuffield Foundation Combined Science Project for Children Aged 11 to 13 Years'. *IPN – Symposium 1970,* über Forschung und Entwicklung Naturwissenschaftlicher Curricula, pp. 169–176.

Provides background information on the Combined Science Project designed for children across the whole ability range for ages 11 to 13. Includes a brief history of the project, its guiding principles, and a description of the materials which have been produced. The main feature of this project is described as the 'provision of an environment in which children can make explorations in the field of science guided by the teacher to the area in which their explorations could lie and helped by him to make reasonable interpretations of their discoveries.

Ennever, L. F., 'Helping Children to Learn Science'. *Dialogue*, No. 1, September 1968, pp. 5–6. United Kingdom.

Describes how a team of educators set about the task of creating the Science 5/13 Program.

Featonby, H., 'Conservation as a Learning Experience'. *The Australian Science Teachers Journal*, Vol. 14, November 1968, pp. 41–44. Australia.

Describes a week-long unit of work in conservation employing a team-teaching approach. A variety of subjects are integrated with science for 6th grade children.

Fensham, P. J. and Fyfield, J. A., 'An Integrative Approach to Science Teacher Education'. *The Australian Science Teachers Journal*, Vol. 18, June 1972, pp. 37–41, Australia.

Describes the integration of science and education courses for future teachers in training at Monash University. Includes a brief description of 'Science Core' which includes common features of all secondary science teaching and discusses current emphasis towards teaching science as an integrated subject.

Genn, J. M., 'School Science and Social Schisms'. *The Australian Science Teachers Journal*, Vol. 10, November 1964, pp. 48–61. Australia.

Considers the relevance of school science teaching to social problems. It deals with some basic issues and considers some of the literature dealing with the social relevance of both science and science teaching.

Gilbert, P. G. S., 'Implications for Central Africa of Developments in Science Curriculum Design'. *Teacher Education in New Countries*, Vol. 5, May 1964. Africa.

Notes that modern educational programmes are not sufficiently attuned to the needs of the particular country and insufficiently integrated with other experiences. Stresses special needs for Africa.

Gillon, Philip and Hadassah Gillon (Eds.), *Science and Education in Developing States*. Proceedings of the Fifth Rehovot Conference. London: Praeger, 1971.

A record of the Fifth Rehovot Conference which met to discuss the most acute of all developmental issues, science and education in the new states. Part I reviews the aims of science and education. Part II surveys science education in the developing states. Part III is concerned with children's needs and opportunities for learning. Part IV is devoted to technological, vocational and out-of-school education. Part V discusses the training of scientists and science teachers. Part VI raises the issues of new methods for new needs.

Gipps, Dr. G. de V., 'Some Qualities Which Industry Seeks in Science Students'. *The Australian Science Teachers' Journal*, Vol. 9, No. 3, November 1963, pp. 35–48. Australia.

An article written by one who is primarily concerned with the output of the teaching process. The author suggests that in order to define the aim of science teaching it is necessary to first examine the working and living environment of the products of teaching, to see how

this teaching can aid in matching the person to the environment. Selecting the manufacturing industry centered around electronics as a particular 'environment', the author describes the characteristics employers might hope to find as a result of the training and teaching in science for such employers as research workers, technologists, and the technicians and clerical workers to be trained by the industry. He notes that for all four groups there is a need for logical and critical thinking and a general appreciation of science in everyday life.

Godfredsen, E. A., 'Aims of a Science Experience in Primary Schools'. *Teacher Education in New Countries,* February 1969, p. 223. Tanzania.

Hall, William C. and Mowl, B. S., 'What does SCISP mean by Integrated Science?' *Education in Science,* Vol. 8, No. 38, June 1970. United Kingdom.

Hall, William C., 'Case Study in Curriculum Decision Making: The Schools Council Integrated Science Project'. *The Australian Science Teachers Journal,* Voi. 17, October 1971, pp. 19–27. Australia.

Describes an integrated program in science for 14–16 year old pupils. The aim of the program is to help prepare pupils for their future job, family responsibilities, leisure activities and to contribute to a student's general education. In this scheme, the processes of science are considered important with all course work directed toward the major concepts of science. 'The concepts are not studied in their entirety at once, but each one is spread out over the length of the course, leading to the development of an idea with age'. The content of the work is based on three fundamental concepts: Building blocks, interactions, and energy. There is no attempt to force integration of content but to ensure that there are no artificial separations. The most important integrating theme is showing that the search for and use of patterns to solve problems is common to all branches of the subject. The social implications and technological applications of science are emphasized throughout the three years of the scheme.

Hall, William C.,'The Need for Integrated Science'. *Education in Science,* Vol. 8, No. 45, November 1971. United Kingdom.

Hall, William C., 'The Schools Council Integrated Science Project'. *Aspects of Education,* No. 12, July 1971; *Geology,* No. 3, 1971; *Physics Education,* Vol. 7, No. 1, January 1972. United Kingdom.

Hawkins, Ian and Symington, David, 'Science Courses in the Education of Primary School Teachers'. *The Australian Science Teachers Journal,* Vol. 18, June 1972, pp. 15–19. Australia.

Summarizes the science courses both required and elective in the three year post-matriculation programs at Toorak Teachers College. The principles upon which the science education courses are built require that the course should be both scholarly and vocational and should conform to the 'post-graduate model of inquiry learning. Its teaching should be inquiry orientated as a model for the future teacher and the course content should be interdisciplinary in nature.

'International Council of Scientific Unions'. *The Education of Teachers for Integrated Science:* (P. E. Richmond Ed.). Report of an International Conference April 1973, London, 1973.

Summaries of the papers which form the bulk of this UNESCO volume and also including details of the organisation of the conference, a list of participants and of submitted papers.

'Integrated Science and the Curriculum Development Process'. *STAN Journal,* May, 1970. Nigeria.

Jacobson, Willard J., 'Integrated Science Programs for Schools and Colleges'. *New Trends in Integrated Science Teaching,* Vol. 1, 1969–1970.

Discusses factors to be considered in the development of integrated science programs including the nature of science and the scientific enterprise, the nature of the learner, the nature of the society and economy, the history of science and science education, and research in science education. Three generalized approaches are discussed: the multiple track approach, the science course approach and an integrated depth approach.

Jungwirth, Ehud, 'Scientists as People'. *Journal of College Science Teaching,* II (2), 1973. Israel.

Reports a study that concentrates on one aspect of understanding science as measured by TOUS. The study indicates that significant differences of opinion regarding personal qualities of scientists exist between a general population of high school pupils, graduating high school biology majors, graduating university students, and professors in the natural sciences. The author suggests the implications of these findings to be that any shortcomings at the high school level in the sphere of 'Understanding Science and Scientists' can be regarded as being the fault of the persons concerned with the training of high-school teachers, both subject-matter specialists and professional educationists.

Kaplan, Eugene, 'The Tel Aviv Elementary Science Teaching Project'. *New Trends in Integrated Science Teaching,* UNESCO, Vol. 1, 1969/70, p. 116.

Kerr, John F., 'Science Teaching and Social Change'. *School Science Review,* Vol. 47, No. 162, March 1966, pp. 301–309. United Kingdom.

Asks the question: 'What is the new view about the purpose of science teaching?' Examines the implications of the new thinking with particular reference to the Nuffield projects. Discusses the general science movement and considers the forces and factors responsible for its growth and sudden decline in popularity. Looks at the factors which are liable to be dominant influences on the new courses and how the new courses will ultimately achieve their objectives.

Knerr, Gunter, 'Pre-school Instruction in the Museum'. *Education in Germany,* Vol. 16, June 1971, pp. 15–16. Federal Republic of Germany.

Describes an experimental project involving pre-school age children in playful science experiments. The author has found the experience particularly attractive to disadvantaged children.

Levine, R. A., 'Integrated Science by Team Teaching'. *The Journal of the Ghana Association of Science Teachers,* Vol. 12, January 1971, pp. 21–25.

Describes an experience in team teaching integrated science. Two major problems were encountered involving the timetable and a deep resistance against the experiment on the part of many students. Possible reasons given for the student reaction included failure on the part of previous teachers to teach the relationships of science and a nervous resistance to change introduced into a very competitive, exam orientated educational system.

Lugg, D., 'The Student'. *The Australian Science Teachers' Journal*, Vol. 10, November 1964, pp. 19–25. Australia.

Examines the role of the student in planning appropriate science programmes. Considers such questions as: at what age does abstract thought become possible? What are children's interests in science in terms of curiosity as revealed by their questions? What are some causes of student failure in performance in science? At what stage should the separate disciplines be taught separately.

McCann, Sister Jacqueline, 'The Relevance of Biology Teaching in Ghana Today'. *The Journal of the Ghana Association of Science Teachers*, Vol. 11, No. 2, June 1970, pp. 14–16. Ghana.

Discusses biology as taught in Ghana in terms of three aims of science education: (1) to impart the available body of scientific facts, theories and general concepts; (2) to impart a clear understanding of science as a progressively evolving human activity which depends on the accurate communication of the facts to society in such a way that society can adapt itself to an ever-changing world; and (3) to gear the science course not only to the pupils themselves but to the social and natural environments in which the pupils live. The author concludes that the biology course given by the Ministry under the influence of the West African Exams Council fails in all three categories. She recommends examining syllabuses in Health Science, Home Management, and Agriculture Management with the aim of including portions of them in the proposed integrated science course to make science more meaningful to all students.

Meyer, G. R., 'Science in Education'. *Scientific Australian*, December 1963. Australia.

Summarizes the structure of the unified science scheme based on the Wyndham report. This program of integrated general science is compulsory for all pupils in New South Wales and is taught for the first four years of the high school. Unique aspects of this program include its flexibility to allow for all types of pupils and to provide experiences catering for all abilities and interests. There is total integration of the four traditional sciences but the methods of integration have been left to the professional integrity of the teacher. Emphasis is upon principles and concepts of science.

Meyer, G. R., 'Vacation Courses for Teachers Conducted by the School of Biological Science'. *The Gazette*, November 1965. Australia.

Describes an in-service training program (vacation courses) conducted to help teachers interpret the work and practical methods of the unified sciences courses. Directors of the program have learned that teachers require facts that can be applied directly to actual teaching situations. They especially need help with interpretation of new topics and in methods of teaching in laboratories and out-of-doors. Teachers do not want advanced information outside the scope of the syllabus.

Meyer, G. R., 'An Appeal to Students in New South Wales – Science for All in the Senior Years of High School'. *The Australian Teacher*, Vol. 43, December 1967. Australia.

Citing the value of science for all students the author gives a brief description of the Third Level Science Program available to fifth and sixth form students who find difficulties with the logical precision of mathematical argument. In this program mathematics is kept at a minimum and what is required is an ability to think quantitatively rather than work through the steps of intricate mathematical problems. A unique aspect of the program is the method of teaching

advocated where a 'very high proportion of the course is best taught away from the school, out in the community or in natural surroundings of bushland, seashore, mountain or valley'.

Meyer, G. R., 'Changing the Curriculum. Developments in Two Regions: United States and East Africa'. *The Australian Teacher,* Vol. 43, No. 2, December 1967. Australia.

The theme of this paper proposes that in the selection of materials for a curriculum to meet the needs of society, one should look not only at criteria derived from an academic discipline; but should also use criteria based on sound objective research in psychology and sociology. The author briefly summarizes educational reform in the United States resulting from the first Soviet Sputnik. He cautions against the transfer of curricula from established countries to developing countries without the establishment of local research groups to work toward a locally orientated program.

Murray, John, 'Linking Science and Mathematics in a Junior Class'. *Science for Primary Schools,* ASE, 1966.

Descriptive account of how an attempt was made to link a simple scientific experiment with mathematics, and how, in consequence, further science work developed.

Northfield, J. R., 'Concurrent Courses in Science Teacher Education'. *The Australian Science Teachers Journal,* Vol. 18, June 1972, pp. 29–35. Australia.

Discusses concurrent courses in Science Teacher Education which integrate subject matter content with education courses. And specifically the B.Sc. (Ed.) course commenced in 1967 at Melbourne University. This program is compared with the 'end-on' type of course in which the great majority of science teachers have been trained in Australia; that is, an academic qualification is followed by a course in education generally of one year. The author notes that since the Melbourne concurrent program began, there have been other courses at La Trobe, James Cook, Macquarie and The University of N. S. W.

Paterson, I. W., 'Why Teach Science?' *The Australian Science Teachers Journal,* Vol. 17, December 1971, pp. 67–72. Australia.

Examines the status of science in the curriculum, the implications for teaching of science. The author suggests that 'science is but one of several ways of interpreting the elements of human existence'; and that the form which science education has taken has seriously 'imbalanced the unity of knowledge and experience'.

Pitre, B. G., 'Today's Education for the Needs of Tomorrow'. *AISTA Physics Study Group.* The Doon School, Dehra Dun., India. December 1972, p. 44.

Reports, activities, seminars and studies in India about the Integrated Science Project at Junior High school level.

Price, R. D., 'Tale of a Horseshoe'. *Dialogue,* No. 2, February 1969, p. 11. United Kingdom.

Brief explanation that the discovery method is common to all the new Nuffield projects whether science, mathematics, or French. Describes the primary program as overlapping subject-matter circles with a large area of common ground in the middle.

'Problem in the Retraining of Teachers in the Use of New Materials in the Philippines'. The Junior Science Conference UNESCO Israel Commission, Rehovot, August 27–28, 1969.

'Report on Project for Science Integration'. *The Journal of the Ghana Association of Science Teachers,* Vol. 12, No. 2, June 1971, pp. 41–42. Ghana.

Report of a workshop for primary and teacher training groups held at University College, Cape Coast, April 4–7, 1971. This workshop was arranged to discuss the recommendations and findings of the Takoradi Workshop. Discussions at the general session centered upon the reasons for teaching science and the effect of a pupil's interest on his science learning. Smaller groups met to discuss the form activities can take, use of the environment, method of approach best suited to the primary school, how science may be taught as an integrated subject, its place in the total program, evaluation, improvised materials, and the role of the science tutor.

Ramsey, G. G. and Dale, L. G., 'The Australian Science Education Project: Its Rationale'. *The Australian Science Teachers' Journal,* Vol. 17, October 1971, pp. 51–57. Australia.

Discusses four guidelines in the development of ASEP, a national effort in Australia. Guideline one raised the question of 'what is science?' and a 5-point environmental scheme was established. Guideline two resulted in a series of unit topics which could be used by the teacher and his students as a springboard to explore the environment. Guideline three takes into account the individual differences which exist among students in terms of stages of intellectual development, reading level and interests. The fourth guideline guarantees the teacher the professional responsibility to choose the most suitable course, topic, method and approach to science for his own students.

Razafy, Eugene, 'Integration of Science and Education in Africa', in P. Gillon and H. Gillon (Eds.). *Science and Education in Developing States,* Proceedings of the Fifth Rehovot Conference. London: Praeger Publishers, 1971, pp. 63–67.

Suggests that the aim of science education at the primary level in the developing African countries should be one of having students acquire the scientific approach. This aim should have its counterpart in a new curriculum which integrates the results of scientific research at all levels of schooling. This implies a new concept in teacher training moving toward a continuous recycling and revising of their scientific knowledge.

Rudd, Allan and Greenwood, W., 'Curriculum in the North West'. *Dialogue,* No. 7, February 1971, pp. 12–13. United Kingdom.

Describes the organizational activities of the North West Curriculum Development Project. This project is concerned with the production and co-ordination, on a regional basis, of seven new two-year courses which it is hoped can be combined into an integrated curriculum. The suggested first year Integrated Studies Programme which was developed includes three stages. Stage One involves a 'core idea' based on 'The Family' and within the class, small groups each choose from a general list of topic headings related to the core idea. In Stage Two, specialist teachers would give 'key' lessons and prepare follow-up work. In Stage Three classes would be replaced by interest groups at which teachers would deal with a variety of types of work and many different areas of study.

Rutherford, James and Marjorie Gardner, 'Integrated Science Teaching'. *New Trends in Integrated Science Teaching,* Vol. 1, 1969–1970, pp. 47–55.

In an article specially written for this volume, the authors discuss the philosophical contention that the universe itself is somehow unified. They suggest the need for buttressing the move toward integrated science with other lines of thought as well. Some of the different ways

in which content can be selected for integrated science programs, how such courses can be integrated, and some of the practical considerations to be taken into account when developing or instituting such programs are given.

Scott, C. B., 'The Place of Technology in an Integrated Curriculum'. *Schools Council Technology Bulletin*, No. 2, March 1968. United Kingdom.

Describes the development of an integrated curriculum in the first three years at an unstreamed comprehensive school. The curriculum aims at providing unity of learning, while also maintaining social unity among the children within their year groups.

Slimming, D., 'A New J. C. Science Course for Swaziland'. *Swaziland Teachers' Journal*, 1972, pp. 25–27. Swaziland.

This article describes the plans to introduce a new science curriculum in Swaziland, Lesotho, and possibly in Botswana. A decision was made to adapt WISCIP material to local needs as the backgrounds of the areas are similar. The adaptation and introduction of the resulting scheme into the schools is planned in three steps involving pre-pilot, pilot and final stages. Description of each stage is given in some detail.

Sneed, G. C., 'Adding Industrial Realism to School Science'. *School Technology Bulletin*, Vol. 4, January 16, 1971. United Kingdom.

'Some Comments on the Integrated Science Syllabus'. *STAN Journal*, September, 1970. Nigeria.

'STEP: A Bold New Approach to High School Science'. *Shiksha Ministry of Education Journal*, Vol. 1, August 1967, pp. 105–109. Nepal.

Describes the pilot phase of a comprehensive program effecting all aspects of high school science. The primary objectives of the program are the development of the students understanding of his physical and biological environment and the development of his competence in dealing with that environment.

'A Study of Teacher Response to Training on APSP Materials'. *Journal of the Science Teachers Association of Nigeria*, Vol. 9, No. 1, 1970, pp. 21–25. Nigeria.

Sumner, W. L., 'School Science in Australia'. *Nature*, Vol. 202, June 20, 1964, p. 1151. Australia.

A book review of the encyclopedia-textbook and accompanying teachers manual developed for the integrated four-year course in New South Wales. Raises the question of determining what is worth teaching and whether such a general science program allows sufficient indepth learning.

Tamir, Pinchas, 'Biology and Agriculture: A Problem in Education'. *Journal of College Science Teaching*, February 1972. Israel.

Published results of a study conducted in 1967–68 which showed that students who had vocational agriculture in high school had significantly poorer performance in all measures of college biology than did their counterparts without such agricultural background. In addition, college students majoring in agriculture showed a consistent trend to achieve less as far as biology is concerned than the rest of the students both in high school and in college. The author speculates on factors accounting for his results and notes that until further insights

are revealed, the relationship between biology and agriculture – often regarded as twin disciplines – remains an educational dilemma.

Theobald, J., 'Is Science a Liberal Study'. *The Australian Science Teachers Journal,* Vol. 10, November 1964, pp. 19–20. Australia.

Discusses the aspects of science which permit it to be classified as a liberal study.

Tinsley, J. D. and Meredith, M. D., 'NCC and Schools Education'. *NCC Newsletter,* No. 21, July/August 1970, pp. 19–20. United Kingdom.

Describes a course in computer appreciation developed to acquaint students in a computer-orientated society with the uses and social implications of computers.

Turnbull, J. J., 'Computer Arts Course for Secondary Schools'. *Leonardo,* Vol. 4, 1971, p. 363. United Kingdom.

Describes a computer appreciation course in Great Britain developed to acquaint students in a computer-orientated society with the uses and social implications of computers.

UNESCO, *Integrated Science Teaching in the Asian Region.* 'Report of the Asian Regional Workshop on The Progress of Integrated Science Teaching'. Manila, Philippines, August 3–17, 1970, p. 44.

Report of the Asian Regional Workshop on 'The Progress of Integrated Science Teaching'. Objectives of the workshop included a review of current progress in the teaching of integrated science in the Asian region, a review of similar developments outside that region considering the relevance and applicability to Asian countries, suggestion of guidelines for future developments and a plan of action to foster collaboration in this field among countries participating in the workshop. Part I of the report presents the concept of integrated science teaching. Part II describes the current situation in the Asian area. Parts III and IV suggest an approach to integrated science teaching and stress the need for its development as a national project. Additional chapters include information on teacher education, science teaching space, facilities and teaching equipment. A plan for future action is discussed.

UNESCO, *New Trends in Integrated Science Teaching,* Vol. 1, Paris, 1971.

A publication intended primarily for the use of those concerned with science curriculum planning and design and with the education of teachers. *New Trends in Integrated Science Teaching* is a collection of papers and articles which concentrates largely on work at the elementary and junior secondary science levels. Part I contains examples of how various workers have attempted to define integrated science and gives some background relating to the trend towards integration. Part II contains statements of the thinking underlying work in progress, together with some examples of this work. Part III is concerned with the psychological and social factors which must be taken into consideration in planning curriculum changes.

UNESCO, *New Trends in Integrated Science Teaching,* Vol. 2, Paris, 1973.

A collection of nine chapters each summarizing the present position in various aspects of integrated science teaching: (1) Aims and objectives, (2) The Rationale, (3) Content and approaches at primary and secondary levels, (4) Teaching methods at primary and secondary levels, (5) Tertiary education, (6) Low-cost apparatus, (7) Environmental education, (8) Evaluation, (9) Integrated science as part of general education.

Examples of integrated science teaching at different levels are also included.

UNESCO/UNICEF, *Planning for Integrated Science Education in Africa.* 'Report of the Workshop for Science Education Program Planners in English-Speaking African Countries', Ibadan, Nigeria, September 20 – October 4, 1971, p. 71.

Report of the African International Workshop held in Ibadan, Nigeria on teaching science with an integrated approach during the first eight or nine years of school. The current situation in Africa is presented followed by the reports of four working groups on Curriculum Planning, Science Teaching Materials and Facilities, Teacher Education for Integrated Science and Evaluation and Testing.

Van Landewijk, J. E. J. M., 'Integrated Science Teaching'. *The Journal of the Ghana Association of Science Teachers,* Vol. 11, January 1970, pp. 10–14. Ghana.

Summary of a discussion seminar at the 15th Eastern Conference of the Ghana Association of Science Teachers reaching the conclusion that integration in the lower forms is indispensable and in higher forms should accompany specialization for the sake of science and pupil alike. In terms of training teachers for integrated science, the author suggests that the best place to start is in the secondary school. He expresses faith in the ability of existing science teachers to begin the process and thus supply the Universities with a group of students to be trained as teachers who have already had some integrated science background. The suggestion is made that lower forms of integration could be accomplished by the phenomena treatment, followed and later accompanied, by the topic-concept treatment. The phenomenon or topic should be taken as a study object in his own right with no conscious or sub-conscious division into different disciplines. The natural relation and context of the object should be maintained. An example is given using the burning phenomenon.

Whiteley, Jack, 'Nuffield Science 5/13'. *The Times Educational Supplement Review,* January 9, 1970, pp. 19–20. United Kingdom.

A brief discussion of the factors leading to the development of Nuffield Science 5/13.

Wilson, J. M., 'Development in Teacher Education for the Teaching of Science'. *Teacher Education in New Countries,* Vol. 12, February 1972, pp. 254–263. Tanzania.

Lists and briefly describes related articles which have appeared in earlier editions of *Teacher Education in New Countries.*

BIBLIOGRAPHY OF ARTICLES PUBLISHED IN THE UNITED STATES OF AMERICA

Adams, Thomas, 'A Review of Unified Science and the High School'. *School Science and Mathematics,* June 1971, pp. 495–500.

Reviews in condensed form the origins, philosophic bases, and history of the movement to unified science curriculum development in United States secondary schools (grades 7–12). Contains numerous quotations from a broad selection of references.

Agin, Michael and Pella, M., 'Teaching Interrelationships of Science and Society Using a Socio-Historical Approach'. *School Science and Mathematics,* April 1972.

Describes the development, field test, and evaluation of a three-week study unit, 'The Development of Atomic Energy and the Social Implications'. The study unit was field tested in two high schools and used reading, films, etc., as instructional modes. An instrument was developed to test for achievement of desired objectives in three groupings: '(1) science and scientists; (2) the inter-relationships of science and society and (3) the atom and atomic energy'. Results were generally favourable.

'American Foundation for Continuing Education'. *Exploring the Universe,* McGraw-Hill Publishing Co., New York, 1963, p. 457.

This is a selection of readings directed to adults and intended to enable the audience (or class using it) to develop a modern outlook on the nature of science. Parts deal with such questions as: 'Is there a scientific method?', 'Is there an order in nature?', 'Is truth scientific?', 'Is there a limit to man's understanding of nature?', and 'How was the universe created?' It could serve as a text for a unified science program at college or senior high school level.

Andres, M., 'Issue-centered Science'. *The Science Teacher,* February 1970, pp. 29–30.

The author sees a major need for the development of some socially relevant, humanistic curriculum options. Various alternatives for integration are examined: chapters from different science courses, topics, or issues. An issue-centered, cross-disciplinary curriculum is seen to hold the most promise. Some ideas for possible issues are given.

Ayers, Jerry B. and Mason, George E., 'Differential Effects of Science – *A Process Approach* upon change in metropolitan readiness test scores among kindergarten children'. *The Reading Teacher,* Vol. 22, No. 5, February 1969, pp. 435–439.

Report of a research study designed to measure the contribution to the teaching and learning of reading at the kindergarten level by 'Science – A Process Approach'. Results showed an increase in the children's reading readiness scores on Number, Listening, and Copying sub-tests and in total test scores for the experimental group using the S-APA program.

Baranski, L. J., 'Unitary Field Theory'. *Scientific Basis for World Civilization,* Christopher Publishing House, Boston, 1960, p. 653.

This book describes the author's work on 'a unitary theory, not only to unify the sciences, but also to provide a rational and universal cognitive system of human values and the empirical unification of the human family'. Drawing ideas from many sources, he postulates the existence of a universal creative-formative process which is responsible for the galaxies, origin of life, the process of evolution, and society. An introduction and history of field theory is followed by chapters tracing development from the origin of life and mind up to ideas for a union of united nations.

Bixby, Louis W., 'Basic Science: Team Teaching Biology, Chemistry, and Physics in a 2-Year Sequence'. *Science and Math. Weekly*, March 1965, pp. 1–4.

Course now in its fourth year. The philosophy is given for merging of the science subject. The course 'starts with those physical concepts necessary to all of science, evolves into application of these concepts to an understanding of chemistry, and finally focusses on biology as the evolutionary end-product of the utilization of physical and chemical principles'. Currently using PSSC, CBA, and BSCS Blue version but planning to produce their own test. Organization includes rotating team teacher responsibilities and individual contact sessions.

Blessing, Leonard C., 'Millburn Senior School'. *Science Education News*, March 1969, pp. 2–3.

A three year unified biology-chemistry-physics course. Texts BSCS Yellow version, Chemistry by Dull and Physics and Chemistry books one and two by Hogg, Bickel, and Little. The article describes the outline of the course. A three-man-team teaches the course.

Botticelli, Charles, *Conceptual Schemes in Science: A Basis for Curriculum Development*, NSTA (USOE project), Washington, 1966, p. 130.

Intended to serve as a guide to using conceptual schemes from *Theory Into Action* as a basis for K-12 science curriculum development. Directed to action at local level using concepts and processes as vertical threads of continuity. Includes chapters in which individuals express their perception of the conceptual foundations of chemistry, physics, biology, and earth science. Also includes chapters: 'The Nature of the Problem' and 'Planning a Local Action Program for Implementing Curriculum Development in Science'. Includes description of ways to translate conceptual schemes into classroom activities.

Brooks, S. M., *Integrated Basic Science*, C. V. Mosby Company, (2nd ed.), St. Louis, 1966, p. 506.

A book written for the nursing profession offering an integrated presentation of science subjects. Basic ideas of the nature of science, and of measurement, physics, inorganic chemistry, organic chemistry, and microbiology are treated first. Then the applications of these fields to the human body are reserved for the appropriate system. Thus, an outline of basic fundamentals is followed by applications of these to the body system. Numerous illustrations and a glossary are included.

Brown, H. E., 'Science in the New Secondary School'. *Teachers College Record*, 1933–34, pp. 694–707.

Complaints against the secondary school have tended to be of a piecemeal nature and little had been done to look at a fundamental philosophy of secondary education. In this article the author discusses the role of science in general and of physical science in particular as related to secondary education. An historical review is given of science enrolments 1890 to 1928, together with some possible reasons for decline in percentage enrolled in high school physical science courses. Criteria for teaching science should not be in terms of formal discipline, knowledge, and college preparation alone. Adjustment to society and to environment should also be included.

Burkman, Ernest, 'New Directions for the High School Science Program'. *The Science Teacher*, February, 1972, pp. 42–44.

Report of the Callaway Gardens Conference supported by NSF and attended by a diverse group of authorities. Problems of present science teaching were seen to be – too group centered, too leader directed, 'pure' and departmentalized, inflexible, and lacking in goals and judgment of effectiveness. It was suggested that science instruction should be modular and unified, designed with minimum expectations to be achieved by all students over all the high school years. One to three-week modular units drawn from all science disciplines, and from outside, should provide for flexibility, different learning rates and interests.

Caldwell, Otis et al, 'Preliminary Report of the Committee on a Unified High School Science Course'. *School Science and Mathematics*, February 1914, pp. 166–168.

Report of a committee of Central Association of Science and Mathematics teachers which explored '. . . better unification in aims and practices in science teaching, and better unification in the content of the science courses of the different years of the high school'. 'The need of unification of sciences is apparent to anyone who has studied the schools at first hand'. Describes objectives and purposes of science in high school. Recommends a course structure composed of one sequence in grades 9–10 and diverging options in grades 11–12.

Carleton, Robert H., 'A Third Course?' *The Physics Teacher*, May 1965, pp. 224–225.

Dr. Carleton argues that there are already enough different kinds of physics courses offered in school to satisfy the need of students interested in science or engineering, those who are non-science college bound and those who will be TV service men or housewives. What is needed is a course in science that would call on all scientific disciplines. In this endeavor teams of scientists from all fields would need to work closely with high school teachers.

Cassidy, H. G., 'Creating an Interdisciplinary Course'. *The Science Teacher – Supplement*, November 1970, pp. 5–7.

Dr. Cassidy describes a course he has developed around ideas of physics and chemistry for college students who are non-science or anti-science students. He used two criteria in choice of material – that the subjects shall be expected to be important in 20 years from now and that background material must be only what is needed to develop the central theme. Intellectual frameworks are discussed first and six weeks are spent on how modern concepts in science are affecting our culture.

Casteel, J. Doyle and Yager, Robert, 'The University of Iowa Science and Culture Project'. *School Science and Mathematics*, May 1968, pp. 412–416.

The project is designed to combine the ideas of both science and social educators. It involves a joint effort to develop instructional materials to demonstrate, how and why science and culture interact, and to suggest the implications for both science and society. The program has been evolving since 1964–5. Units were developed by the Science and Social Studies facilities at the University of Iowa Experimental School. The course is designed for high school students.

'Center for Unified Science Education'. *Abstracts of Research and Evaluative Studies Related to Unified Science Education*, Ohio State University, September 1972, p. 5.

This collection of abstracts reports results of 17 evaluative studies conducted in conjunc-

tion with different unified science programs. Most of the studies reported have *not* appeared in journal articles. The collection is being updated continuously as new or previously unknown material is identified.

'Center for Unified Science Education'. *Abstracts of Unified Science Programs,* Ohio State University, September 1972, p. 21.

This collection of abstracts contains 81 separate entries and includes unified science programs at primary, secondary, and tertiary levels on an international basis. Information was obtained principally through a survey conducted in the summer of 1972. The collection is continuously updated as further information becomes available.

'Center for Unified Science Education'. *Prism II* (v.1, n.1), Ohio State University, Autumn 1972, p. 8.

This is the quarterly newsletter that presents articles about unified science education and describes activities and services of the Center for Unified Science Education. The Center was established in 1972 by a grant from the National Science Foundation to the Federation for Unified Science Education (FUSE).

Chisman, Dennis G., 'Teaching Integrated Science'. *The Science Teacher,* February 1973, pp. 20–22.

Integrated science teaching covers approaches '(a) in which concepts and principles of science are presented in such a way as to express the fundamental unity of scientific thought, (b) which emphasize the processes and methodology of the scientific outlook, and (c) which embody a scientific study of the environment and the technological requirements of everyday life'. The teaching of sciences at different school levels is discussed together with models of integrated science – process, topic, themes, applied science, environmental, project, concepts, and patterns approaches. Implications for teacher education are mentioned

COPES, *Conceptually Orientated Program in Elementary Science,* New York University, 1971, p. 16.

Describes the COPES program and materials in elementary science (grades K-6). Program is based on five conceptual schemes, the development of which is done concurrently and 'interwoven with each other'. Schemes used are: The Structural Units of the Universe, Interaction and Change, The Degradation of Energy, The Statistical View of Nature, and The Conservation of Energy. Implies future extension to secondary school.

DeRose, James V., 'Contributions to a Unified Science Program'. *The Science Teacher,* May 1965, p. 83.

These are comments by Dr. DeRose in connection with the NSTA's 1964 Curriculum Committee outlines on conceptual schemes and the process of science. He sees these statements as giving direction for the organization of science. 'Each conceptual scheme must be analyzed into a hierarchy of contributing facts, experiences, and ideas which together give it meaning'. Activities can then be developed to constitute the curriculum of the unified science program.

Dunlop, J. L. and Alberding, A. P., 'Interdepartmental Team Teaching – A Physics-Math. Course'. *The Physics Teacher,* March 1969, pp. 163–165.

The article describes a new course developed to help boost enrollment in physics and to provide necessary mathematics at Catalina High School, Tucson, Arizona. It consisted of a full year of physics (PSSC) and a half year each of algebra and trigonometry. A subjective evaluation found that students in these combined studies were about the same as for other physics classes even though the students in combined studies had lower over-all high school grade averages, and students reported that the mathematics had more meaning as it was applied.

'Educational Policies Commission'. *Education and the Spirit of Science*, NEA, Washington, 1966, p. 34.

Develops the concept of the 'spirit of science' as something that transcends the ordinary notion of science and is more like '. . . a spirit of rational inquiry, driven by a belief in its efficacy and by restless curiosity'. Thus, science is seen as a more humanistic enterprise. Identifies seven 'values that underlie science: questioning of all things, search for data and their meaning, demand for verification, respect for logic, consideration of premises, consideration of consequences'.

'Educational Research Council'. *ERC Science Problems: A High School Program of Individualized Instruction in Science*, Cleveland, 1972, p. 9.

Presents a description of the program. Its five outstanding features are that it: (1) is learner centered; (2) emphasizes process, content, and attitudinal objectives; (3) is classroom tested; (4) is multidisciplinary; (5) has complete and inexpensive instructional packages. Components of the courses are divided into two phases: Phase A presents an introduction to individual inquiry and Phase B presents the main body of the course – the nine problem areas.

Fiasca, M. A., 'Integration of the Sciences'. *The American Biology Teacher*, April 1970, pp. 225–226.

The author describes the growing interest in integrated science and gives examples of educational values that can be derived from course integration: (1) the student can be absorbed in the learning task; (2) duplication of material avoided, (3) logical content development is possible; (4) the student can appreciate the unit of science; (5) the thought processes of a working scientist as well as have, (6) an increased science background. Brief references made to the Portland project and some problems encountered in implementation are mentioned as well as some useful suggestions.

Fiasca, Michael, 'UNESCO Helps Science Integrate'. *The Science Teacher*, February 1973, pp. 23–24.

UNESCO launched its program on behalf of integrated science in 1968. Its plan of action is: '(1) to prepare a series of publications on integrated science teaching; (2) to provide technical services to member states through UNESCO field experts concerned with integrated science teaching; (3) to promote experimental projects for the development of new methods and materials for integrated science at primary and lower secondary levels; and (4) to organize a series of international, national, and regional integrated science teaching workshops'. The article describes how these aims have been and are being achieved.

Fishleder, Jack, 'The Science Curriculum Improvement Study'. *The American Biology Teacher,* Vol. 34, No. 7, October 1972, pp. 391.

Of the three federally-assisted elementary programs of national importance, SCIS is described as the most promising for expanding environmental education because it centers attention on ecological and biological questions. The author also suggests that the laboratory-centered units of the program provide a natural interdisciplinary bio-physical environment which could be readily given a distinct social dimension.

Forbs, L. et al, 'Oceanography: A Vehicle for Integrating Science Concepts'. *The Science Teacher,* March 1969, pp. 40–42.

Describes the use of the Oceanographic Education Center at Falmouth, Massachusetts. One of their projects was to have each eighth grade student of the Falmouth Intermediate Schools come for one week during the school year. Studies of an interdisciplinary nature centered around the estuary with students' inter-relating temperature, salinity, and bathymetric studies with the plankton and bottom-living animals. The 'scientific method' arose naturally and necessary facts and skills were learned incidentally.

Fox, Fred W., 'After Concept and Process'. *The Science Teacher,* Vol. 40, No. 4, April 1973, pp. 19–20.

The author suggests that we are in the final act of the science education drama which spanned the 1960's when the plot centered on 'concept' and 'process'. He offers two lists of generalizations. The first list represents a rephrasing of some of the broad concepts and process statements currently found in secondary science education and shows that moral and science-and-society implication have actually been prevalent in what we have been teaching. The second list of concepts focuses on the issues of science and society, man and his environment, and moral values and science. The author suggests this second list, to which students may be exposed in current and developing science programs can add a gravely needed ethical dimension to education through science.

Fox, Fred, 'Education and the Spirit of Science – The New Challenge'. *The Science Teacher,* November 1966, pp. 58–59.

This article describes the potential impact on the setting of new objectives for science teaching caused by the publication of *Education and the Spirit of Science* (Educational Policies Commission, National Education Association, Washington 1966). The latter emphasizes seven values that underlie all science and which should permeate the content of all science education.

The author feels that this small book may well become recognized as one of the '. . . monumental pieces of literature in science education . . .'.

Francis, Gladys and Hill, Casper, 'A Unified Program in Science for Grades Nine through Twelve'. *The Science Teacher,* January 1966, pp. 34–36.

Describes the historical development and the present status of the unified science program at *Dwight Morrow High School* in Englewood, New Jersey. Cites perceived strengths, weaknesses, and problems of the program.

Fuller, E. C., 'Combining First Year Chemistry and Physics for Science Majors'. *Journal of Chemical Education,* March 1964, pp. 136–138.

Among advantages claimed for combined courses are: (1) a saving in time; (2) an integrated idea for future secondary school teachers; (3) a widened outlook on science and how it develops; (4) the subject matters complement each other; (5) applying a given concept to both fields deepens the students' understanding; and (6) the faculty also plans and works together. Some problems encountered are also outlined. The article gives an overall description of some parts of the course together with some specific ideas.

Gardner, Marjorie, 'Symposium: Techniques that Work in Integrated Science Modules and Minicourses for Integrated Science'. *The Science Teacher*, February 1973, pp. 31–32.

Several modules from the Interdisciplinary Approaches to Chemistry (IAC) program are briefly described. These integrate important concepts in two or more traditional areas of science. It is suggested that 'many of the problems related to the teaching of integrated science could be overcome by using a well-established discipline such as chemistry as a foundation for curriculum development'. There are trends away from highly structured disciplined-based science toward interchangeable modules and integrated science; from science education for college to science education for scientific literacy. Modules offer a way to implement these trends.

Geisert, Paul, 'The Greening of Science Teachers'. *The Science Teacher*, Vol. 40, No. 2, February 1973, pp. 42–43.

Describes a survey, the results of which indicate respondents overwhelmingly feel science teachers should hold a value system strongly orientated toward humans. The author suggests that science teachers should employ their 'scientific training' to sense this general social trend away from pure sciences. It may inspire some thinking about the directions science education must take in the next five or ten years.

George, Kenneth and Wrench, Susan, 'Are You Prepared to Teach a Course in Unified Science?'. *School Science and Mathematics*, May 1966, pp. 429–436.

Presents a brief rationale for unified science courses in high schools and cites a few examples. Describes the results of a survey of unified science teachers to determine what, if any, unique characteristics they have. None reported. Some differences reported for backgrounds of teachers in integrated chemistry-physics and those in courses unifying many sciences. The latter had taught fewer years and had fewer hours of college level physics and chemistry. Some recommendations on what courses and depth of preparation are recommended by unified science teachers for prospective unified science teachers.

Goar, F. D., Holm, P. L. and Wasson, J. K., 'The Moline Project – A Two-Year Integrated Science Project'. *The Science Teacher*, December 1966, pp. 40–41.

Describes the rationale and history of development of a two-year combination chemistry-physics course at Moline, Illinois, Senior High School.

Goar, F. Darrell, 'Toward Humanization and Individualization of Science (T.H.I.S.)'. *Illinois Journal of Education*, April 1971, pp. 33–43.

Presents the rationale for an historical development of the T.H.I.S. project. Describes basis for team teaching strategies. Gives topical outline for three year program. Lists specific educational objectives for program.

Goar, F. Darrell, 'Toward Humanization and Individualization of Science'. *The Science Teacher,* September 1972, pp. 23–26.

The article gives questions most often asked by visitors to Moline Secondary School concerning their science instruction, together with answers from the school staff. In this way are described the school staff's interpretation of 'humanization' and 'individualization' as well as descriptions of how these are achieved in the T.H.I.S. program. Specific advice is also given on how to set up a similar program.

Gratz, Pauline, *Integrated Science – An Interdisciplinary Approach,* F. A. Davis Company, Philadelphia, 1966, p. 103.

This is a course outline prepared for science teachers who work with non-science majors in college. The introduction includes a discussion of general education and rationale and criteria of an interdisciplinary course. The unifying concept for the course is 'Man is an organism, interdependent with other organisms, adapted for change in a constantly changing biological, physical, chemical and psycho-social environment'. Ten units are outlined, each with its own generalizations and suggestions for teaching. References and lists of experiments are also given.

Gratz, Pauline, 'An Interdisciplinary Approach to Science Teaching for General Education on the College Level'. *Science Education,* April 1966, pp. 285–292.

Describes the rationale for and objectives of the course developed at Teachers College, Columbia University for undergraduates who were not majoring in science. It was offered as an addition to regular general education courses on science and extended over two semesters and carried eight credits. 'The approach to the course is physiological since from this point of view the interdependence of the field of biology, chemistry, physics, and mathematics can be ulilized and demonstrated'.

Haggis, Sheila, 'Science Education in National Development'. *The Science Teacher,* February 1972, pp. 49–51.

Describes how science curriculum develops in an emerging nation (Nigeria) and some of the ways UNESCO is contributing to this (and other) development. The latter emphasizes cross-disciplinary activities 'concerned with problems or aspects of science education which affect the teaching of all the various scientific disciplines'.

Haney, Richard E., *The Changing Curriculum: Science,* ASCD, Washington, 1966, p. 64.

Identifies general objectives that should form a core around which a science program should be planned; the pupil should: (1) acquire knowledge which he can use to explain, predict, and control natural phenomena; (2) grow in his ability to engage in the processes of science and to apply these in his daily life; (3) acquire attitudes of scientists and apply them; (4) come to understand the various inter-relationships between science and society; (5) learn numerous manipulative skills through the study of science, and (6) acquire a variety of interests that may lead to hobbies and vocation.

Haskell, E. F., 'Assembly of the Sciences into a Single Discipline'. *The Science Teacher – Supplement,* November 1970, pp. 8–15.

An overview of science is given. An organized hierarchy is described that shows the relationships between atomic particles, atoms, molecules, plant ecosystems, animal ecosystems, and human cultures. Each of these levels has its own parts that are classified and help in understanding of other levels. This is an extremely useful article for stimulating thought and discussion about underlying principles of science and the relation of science to philosophy.

Haskell, E. F., *Full Circle – The Moral Force of Unified Science*, Gordon and Breach, New York, 1972, p. 256.

Presents one scheme in which all of the specialized sciences can be assembled. The major thesis is that 'all natural systems have a common underlying structure; and that the Periodic Table of Chemical Elements is its special atomic case. The author reasons that this system is the 'Universal Characteristic' predicted by Leibniz. One section of the book deals with 'The Role of Unified Science in Vitalizing Research and Education'.

Hayward, O. T., 'Geology as an Interdisciplinary Experimental Science'. *Journal of Geological Education*, April 1966, pp. 66–68.

Reports some of the implications for geology courses in college resulting from the conclusions of the 1965 College Commissions Conference on Interdisciplinary Activities. In this conference, '. . . a group of chemists, physicists, biologists, engineers, and geologists reviewed the problem of introductory science and of interdisciplinary co-operation'. Emphasized the lack of relevance perceived by geology students for chemistry and physics courses while the latter '. . . can easily lose sight of the real world'. Announces plan to develop 10–12 problem orientated brochures to utilize interdisciplinarity. No concern for non-science majors expressed.

Hayward, O. T., 'Integrated Science – The Untidy Field'. *The Science Teacher*, February 1973, pp. 32–33.

The author describes the disservice we do to students by working on artificial questions that have right answers – a neat and tidy science. But out of school the student will have to consider problems that weren't in the book, the phrase questions that haven't been asked before, and he will never know if his answers are the best ones. Real science is integrated – it isn't neat and tidy. Some suggestions are given as to how to study geology in the real world so that students realize that real problems cannot be solved within the narrow confines of disciplinary science. Each student should identify his own specific problem and work out how to find his own answers.

Herr, Lowell, 'Unified Science: A Solution to Physics Enrollment'. *The Physics Teacher*, May 1971.

Suggests that the presence of a unified science curriculum is one way to combat declining enrollments in elective physics courses.

Hilton, A. M., 'Cybernetics and Cybernation'. *The Science Teacher*, February 1973, pp. 34–40.

The author believes science teachers have a role to play in making young people aware of the vast potential of scientific knowledge and technical tools for building a new world. She discusses cybernetics – the ancient philosophy of relationship – and describes several different kinds of systems ('any cohesive collection of items that are dynamically related'). The parts of a communication system are discussed to help in an understanding of cybernation – 'the production method by means of machine systems under the direction and control of a computing machine'. She also discusses the difficulties, and advantages, of trying to build mathematical models of our socioeconomic system. A thought provoking new look at systems and their role in human history.

Hofman, Emil T., 'Science Education to Meet the Needs of the Modern World'. *Science Teacher*, May 1970, pp. 40–45.

Convinced of the need for changes in the mode of science and engineering education to meet the demands of the modern world, the author proposes that: (1) college science and engineering curricula should be flexible enough to permit students to pursue various areas as their knowledge, interests, and abilities develop and change; (2) specialized science courses be continued for capable secondary students; and (3) a unified science course be designed for other secondary students.

Hogg, J. C., Bickel, C. L., and Little, E. P., *Physics and Chemistry – A Unified Approach* (Book One), Van Nostrand Co., 1960, p. 374.

This is the first of a pair of integrated books on Physics and Chemistry for grades 11 and 12. Some chapters involve only physics, a few only chemistry; but most are concerned with both physics and chemistry. A concept such as energy is treated in several chapters, each time developing a deeper understanding. The chapter headings of one unit are: Temperature and Expansion, Heat and Its Measurement, Heat from Electricity, Evaporation and Vapor Pressure, the Liquefacation of Gases, Carbon Dioxide, and Heat Energy in Chemical Reactions.

Hudes, Isidore and Moriber, George, 'Integrated Science Education for Nonscience Students in a Large University. *The Science Teacher*, February 1968, pp. 39–42.

Describes three one-year courses developed at Brooklyn College, City University of New York. First year is physical science, second year a choice of biology or geology. All planned to achieve three basic aims: provide knowledge and appreciation of principles and theories of natural science, illustrate the various methods of science, show inter-relation and interdependence of the various branches of science. Aims, objectives, and content evolves through bi-weekly staff meetings.

Hurd, Paul DeHart, 'Educational Goals in Science for the 1970's'. Paper presented at the NSTA Meeting, New York City, April 1972, p. 8.

In a speech presented at the National Science Teachers Association (NSTA) convention in New York in April, '72. Dr. Hurd examines social problems and goals in the perspectives of scientific and technological influences. He states that one of the most important issues to consider is how to bridge the various gaps that exist between science, society, technology, the individual, and the school curriculum. To achieve the objectives of acculturation, skill acquisition, and intellectual attitudes, he advocates that science be taught in the context of society, with a focus upon the welfare of mankind. Therefore, emphasis upon application to human affairs is needed, requiring a more holistic view of curriculum goals. Curricula should be planned for the future.

Hurd, Paul DeHart, 'The Changing Rationale for the Teaching of Science'. A paper presented at the Educational Research Council of America, January 1973, p. 16.

The curriculum revision efforts of the 50's and 60's had as primary goals the knowledge of theoretical investigative and structural bases of particular disciplines. But the 'specialization reflected in conventional science courses not only limits an understanding of modern science but also the resolving of problems besetting society'. 'One of the most important issues we need to consider is how to bridge the various gaps that exist between science, society, and technology; the individual and the school curriculum'. This will require that in the 70's 'we teach science with as much emphasis upon its application to human affairs as upon its theoretical structure and investigative processes'. Teaching cohesive integrated science with a plurality of approaches is seen as a possible way to achieve these objectives.

Hurd, Paul DeHart, 'Integrated Science'. *The Science Teacher*, February 1973, pp. 18–19.

The author says that 'discipline-centered science curricula developed during the 1960's are being assessed as inappropriate for the 1970's and 1980's' . . . 'Knowledge has become locked into disciplines and has increasingly become unavailable to the general public', and that what is taught in school is 'foreign' to the 'real world' of common experience. What is needed is a new synthesis of subject matter less orientated to revealing the structure of disciplines. An integrated science program for the non-specialist is suggested – one that would unify human experience, provide insight into real problems, and allow for many approaches and many answers.

Jacobson, Willard, 'A Broader System of Science and Technology', Paper presented to Symposium on Science and Society, AERA, February 1968, p. 8.

Presents thesis that '. . . for research and curriculum development in many cases it would be desirable to consider a broader system of science – a system that includes pure science, applied science, technology, and social and economic development'. Gives potential desirable outcome that might result from doing so.

Karplus, Robert, 'The Science Curriculum Improvement Study'. *Journal of Research in Science Teaching*, Vol. 2, 1964, pp. 293–303.

Describes the rationale and guidelines for the Science Curriculum Improvement Study (SCIS) and how it relates to the evolution of science curriculums in the U.S.A. The chief objective of the project is '. . . to develop a teaching program (which will) increase scientific literacy in the school and adult populations'.

Several key tasks in conducting the project are identified: 'to formulate a view of the nature and structure of science', 'devise learning experiences that (connect) pupils' intuitive attitudes and (modern science)' and to evaluate what has been learned.

Describes briefly some activities for early elementary levels: 'interaction and systems', 'material objects', 'variation and measurement', and 'relativity'.

Karplus, Robert, 'Science in the Elementary School'. *New Development in Elementary School Science: A Conference, Frontiers of Science Foundation of Oklahoma*, February 1964.

The author points out some of the characteristics of natural phenomena that seem to be especially significant for general education and notes that they illustrate fundamental ways in which the scientific point of view differs from and goes beyond the natural logic or commonsense point of view that individuals in our culture develop as they grow up. He recommends that science instruction should start during the elementary school years and must reflect the nature of science as a human activity. The major portion of the article outlines the characteristics of the science program, SCIS, which has as its objective the advancement of scientific literacy.

Kessen, William, 'Statement of Purpose and Objectives of Science Education in School'. *Journal of Research in Science Teaching,* 1964, pp. 3–6.

Describes the rationale and guiding principles used in developing the AAAS elementary science materials. 'It seeks to go beyond the present fruitful studies in course development, so largely devoted to each of the various sciences as separate entities, and to weld them into a harmonious whole that will be built into the educational birthright of each of us'. 'Science is more than a body of facts, a collection of principles, and a set of machines for measurement; it is structured and directed way of asking and answering questions'.

Klopfer, Leopold, 'Integrated Science for the Secondary School: Process, Progress, and Prospects'. *The Science Teacher,* November 1966, pp. 27–31.

Applauds the results of the national curriculum projects (PSSC, etc.) but asks whether '. . . the function of general education is best served by requiring students to enroll in specialized science courses which mimic the organization of university departments?' Describes the courses, Natural Science I and II, developed at the laboratory school of the University of Chicago for grades 9 and 10. Commends the future development of a plurality of unified science courses to meet local needs.

Klopfer, Leopold and McCann, Donald, 'Evaluation in Unified Science: Measuring the Effectiveness of the Natural Science Course at the University of Chicago High School'. *Science Education,* March 1969, pp. 155–164.

Presents the procedures, results and conclusions of a study designed to evaluate the effectiveness of a unified natural science course compared to the Time, Space, and Matter course for ninth grade students at the University of Chicago Lab. School. Student responses to individual test items were analyzed. Identified areas of success and failure within courses.

Laszlo, E., *Introduction to Systems Philosophy,* Gordon and Breach, New York, 1972, p. 328.

This text is the first comprehensive treatment of systems philosophy. It seeks to find the theoretical instrument for assuring the mutual relevance of scientific information and philosophic meaning. 'Extended into a general systems philosophy, this instrument can polarize the contemporary theoretical scene as a magnet polarizes a field of charged particles: by ordering the formerly random segments into a meaningful pattern'. This extension is the basis of the book and presents one possible plan on which to base a unified science program or a part of it.

Lerner, Morris, 'Integrated Science – Physics and Chemistry'. *The Science Teacher,* February 1964, pp. 37–38.

Describes the rationale for and some results of the integrated physics-chemistry course at Barringer High School, Newark, New Jersey. In general, a favorability was shown for those students in the combined course compared to those who were in separate chemistry and physics courses in the same school at the same time.

Lindsay, Bruce, 'A Unified Approach to Science Teaching'. *Journal of Research in Science Teaching,* 1970, pp. 209–215.

Discusses the proposition that science is a method for the description, creation, and understanding of human experience, and as such, should be taught in a unified approach in secondary schools and in general education courses at the college level. Describes some desirable charac-

teristics of such courses. Based on an invited paper at National Association for Research in Science Teaching.

Linn, Marcia C., 'An Experiential Science Curriculum for the Visually Impaired'. *Exceptional Children*, September 1972, pp. 37–42.

Adaptation and evaluation of a materials-centered, experiential curriculum for elementary-age, visually-impaired children is described. The adaptations of both the physical and the life science units can be used in classes with one or two visually-impaired students and also in classes of all visually-impaired students. Evaluation measures were designed to assess the major objectives of each unit. Classroom trials of two of the adapted units revealed that visually-impaired students made significant gains in understanding both content and process objectives of the units.

Livermore, Arthur H., 'AAAS Commission on Science Education Elementary Science Program'. *Journal of Chemical Education*, Vol. 43, No. 5, May 1966, pp. 270–272.

Describes the early development of the elementary science program, *Science – A Process Approach*. The materials consist of a series of exercises designed to improve the child's skills in using the processes of science. Content is selected from various science disciplines. 'In a sense, process is the warp and content the woof of the fabric of the AAAS elementary science program'.

Livermore, Arthur H., 'The Process Approach of the AAAS Commission on Science Education'. *Journal of Research in Science Teaching*, 1964, pp. 271–282.

Describes the rationale for and procedures of developing Science – A Process Approach for elementary grades. Identified 14 processes as a 'structured and directed way of asking questions and answering them' as being an integral part of science as much as it is a body of facts, principles, etc.

Lowry, George G., 'An Integrated Physics-Chemistry Curriculum for Science Majors'. *Journal of Chemical Education*, June 1969, pp. 146–148.

Describes a four year course for majors in chemistry, chemistry and physics, or physics at Claremont Men's College, Claremont, California. In the first semester of freshman year, physics and chemistry are combined and followed in the second semester by concurrent courses stressing applications to physics and chemistry. An outline description is given for all the courses. Limitations and advantages of the program are described.

McCurdy, Donald and Fisher, Robert, 'Physical Science Project – An Individualized Two-year Chemistry-Physics Course'. *The Science Teacher*, December 1969, pp. 60–63.

Describes the Nebraska Physical Science Project and its origin, objectives, and format. Based on a series of 'individualized learning packages' through which the student proceeds at his own rate and '. . . exercises many choices relative to which learning activities to pursue . . .'. Learning packages include 'optional' topics as: 'air pollution, desalination of seawater', etc. Designed to use multi-media, to achieve a large list of behavioral objectives, and to place the teacher in role of consultant.

Margeneau, Henry, *The Nature of Physical Reality,* McGraw-Hill, New York, 1950, p. 479.

Attempts to analyze all experience including empirical knowledge and builds an epistemology that is consistent with both modern and classical physics and with most of science in general. This epistemology emphasizes the role of 'constructs' as a way of imposing order on natural phenomena. Has strong implications for identifying the 'essence' of science that should permeate all programs in science for general or liberal education.

Margeneau, Henry, *Integrative Principles of Modern Thought,* Gordon and Breach, New York, 1972, p. 522.

Volume 3 in a series of 'Current Topics of Contempory Thought' devoted to philosophy, science, and the humanities. The book presents what might be called synopses of useful concepts and theories for integrating modern knowledge. Integrative principles are presented by a variety of writers for fields such as Science, Physics, Biology, Human Society, and Art and Science. Quantization, Order and Science and Faith are also discussed.

Marshall, J. Stanley and Burkman, Ernest, *Current Trends in Science Education,* Library of Education, New York, 1966, p. 115.

Comments mainly on rationale, impact, and characteristics of the national curriculum projects. The latter are viewed as reversing a trend toward science in which '. . . students should be encouraged to think in terms of science as a whole rather than considering it as a collection of separate disciplines'. However, brief mention is made that unified science courses probably should be developed 'parallel to the present courses in the separate sciences'.

Mayor, John R., 'Science and Mathematics in the Elementary School'. *The Arithmetic Teacher,* Vol. 14, December 1967, pp. 629–635.

The author shows how 'Science – A Process Approach' demonstrates the close relationship between mathematics and science at the elementary school level and the desirability and feasibility of planning mathematics and science programs co-operatively. He briefly reviews the S-APA exercises concerned with topics usually included in mathematics programs.

Mayor, John R., 'Science and Mathematics: 1970s – A Decade of Change'. *The Arithmetic Teacher,* Vol. 17, April 1970, pp. 293–297.

The author suggests that two important first steps in bringing science and mathematics together will be the early introduction of graphing and teaching of notation for rational numbers in decimal form and the use of rational numbers expressed in this form. He calls attention to two programs already employing these steps: MINNEMAST and Science – A Process Approach, and recommends that every school program should provide for them by 1975 or earlier. Two other goals proposed are, that by 1985, all elementary school science and mathematics programs should be carefully correlated if not fully integrated, and by 1995 mathematics, the language of science must clearly also be the language of every citizen.

McFee, Evan and Robert D. Lehman, 'SCIS and Bilingual Education in Science'. *The American Biology Teacher,* Vol. 35, No. 5, May 1973, pp. 260–261, 272.

Suggests that because SCIS is action – and materials-centered and uses a diversity of materials and investigations to enrich vocabulary, it is especially well suited to the needs of bilingual schools. Notes that Cleveland, Cincinnati, New York, and several other cities use SCIS in

co-ordination with their reading programs as well as finding the units helpful as part of the overall effort to improve children's oral language.

Merry, Raymond, 'Science and Society – A Step Toward Relevance in Science for High School Students'. *The Science Teacher,* February 1973, pp. 47–48.

Describes a course developed in a small secondary school as an elective in grades 10–12. Lists seven specific goals that are derived from a unified science viewpoint (e.g., 'increase ability in the use and understanding of the methods of science . . . controlled experiment, critical analysis . . . scientific law'). Twelve topics (e.g., 'Ecosystems', 'Nature and History of Science', 'Values') contsitutes the course. The main text used is *The New Technology and Human Values* (Burke, J. G., editor, Wadsworth Publishing, 1966). Identifies a few learning activities: lectures, discussions, films, and visitation. No mention is made of laboratory activities or evaluation procedures.

Moulton, James M., 'Rationale for Sequence of High School Science Courses: Argument for Change', Paper presented to AAAS Co-operative Committee on the Teaching of Science and Mathematics, Beloit (WIS), May 1968, p. 12.

Reviews the shortcomings and needed changes in high school science curriculum from the point of view of a college biology teacher. Regards, '. . . the trend toward unified science programs . . . likely to have ultimately a more profound effect on science education than any other'. 'Where a traditional science curriculum exists . . . (it should be ordered) . . . chemistry, biology, physics (but) far preferable is a unified science program extending over three years'.

Munn, R. J., 'Symposium: Ways to Integrate Science – The British Open University Approach'. *The Science Teacher,* February 1973, pp. 27–28.

The British Open University has been in operation for approximately two years. It was designed to bring a university education within reach of persons not attending a regular university . . . 'it has no formal academic admission requirements and conducts its courses by correspondence supplemented by radio, television, and local study centers'. The Science Foundation course, which is integrated, multidisciplinary, and modular is briefly described. It is supported by a home experiment kit and presents and explains 'some concepts and principles that are important in modern science' and shows how science, technology, and society are inter-related. Common methods, techniques, and philosophy of areas of science are covered. Some U.S.A. universities are pilot testing the ideas.

National Science Teachers Association, 'School Science Education for the 70's'. *The Science Teacher,* November 1971, pp. 46–51.

This is a position statement on science curriculum development. Itemizes 'general goals of science education' as including some general goals of all education and the specific goal of developing 'scientifically literate citizens'. The latter concept is defined by a list of 21 factors which includes both cognitive and attitudinal items. Makes eight specific recommendations for K-12 curriculum development including 'science (should) be taught as a unified discipline, integrated and/or co-ordinated with other disciplines such as mathematics, social science, . . . (etc.)'. Includes guidelines on 'appropriateness of objectives', 'selection of content, methodology, and learning experiences', evaluation, etc.

Nesbitt, H. H. J., and Hart, John, 'Science 100'. *Science,* November 14, 1964, pp. 895–896.

Describes a college course for non-science majors to meet the problem of, '. . . imparting to arts students, in 26 weeks, a smidgen of what science is all about'. Original papers used as text material.

Neurath, Otto et al, *Foundations of the Unity of Science,* University of Chicago Press, Chicago and London, 1971, Vol. I, p. 760; Vol. II, p. 1023.

These two volumes contain a collection of monographs authored by scientists, philosophers, and educators over the years 1938–1969. Some papers were presented at one of the six International Congresses for the Unity of Science. The collection was conceived as an introduction to the *International Encyclopedia of Unified Science* but which was obviated by World War II and the deaths of key persons in the movement. Examples of monographs contained are: 'Logical Foundations of the Unity of Science', 'Unity of Science as a Social Problem', 'Foundations of the Social Sciences', and 'The Structure of Scientific Revolutions (second edition, enlarged)'.

Novick, Shimshon and Sutman, Frank X., 'A Socially Orientated Approach Through Carbon Compound Chemistry'. *The Science Teacher,* Vol. 40, No. 2, February 1973, pp. 50–52.

This article reports the development of a socially-orientated approach to science through carbon compound chemistry for non-science majors at the secondary school level used in the United States and In Israel. The aims of the course are to help students understand the relation of chemistry to some of today's social concerns. The program is developed as a text with materials designed to be taught utilizing a laboratory-orientated approach. A brief discussion is included on the results of a pilot test of the materials with tenth grade students in the United States.

Parsegian, V. L., *Report on the AAAS Session Science Courses for Baccalaureate Education,* Rensselaer Polytechnic Institute, December 1967, p. 3.

Summarizes the proceedings of the AAAS Session devoted to the theme, 'An Integrated course in science is feasible'. V. L. Parsegian described a college program, Introduction to Natural Science, designed for science and non-science majors offering an historical and philosophical approach to physical and biological sciences. Some topics treated are systems, feedback and cybernetics, probability and statistics in nature, and limitations of observation and measurement. Teachers of the course presented feedback information on their experiences. Parts of the course have been successfully used, for example, with architects, non-science freshmen and women preparing to teach elementary grades.

Parsegian, V. Lawrence, 'What Makes Studies Interdisciplinary?'. *Journal of College Science Teaching,* February 1972.

The author proposes that specialization in any technical or non-technical area acquires firmer foundation when it emerges from an educational base that includes some knowledge of the social and material framework within which man's society functions, and some knowledge, as well; of the knowns and unknowns in conceptual form derived from both the physical and life sciences. He suggests also, the importance of framing the entire educational experience within the perspective of historical time and evolutionary progression that maintains some awareness of common fate for the future. He briefly describes a project underway at

Renssalaer Polytechnic Institute, 'Building Educational Bridges Between Science and the Humanities', which is developing a course of studies suitable for college students of all professional interests. One of several major themes for the course focuses on environmental-ecological issues.

Pella, Milton, 'Science Needed by All'. *The Science Teacher,* December 1965, pp. 51–52.

Presents an argument for requiring science of all students in all four years of high school by providing appropriate courses. Reviews several reasons for viewing all science as being part of a larger whole and which should be used as the basis for developing appropriate courses.

Pella, Milton O., 'Concept Learning in Science'. *The Science Teacher,* October 1966, pp. 31–34.

Concepts are seen as the 'warp and woof of science' allowing for classification and summarizing of knowledge. Several concepts are described and examined, and a list of characteristics of concepts is given. Questions for the effective teaching of concepts are posed.

Pfeiffer, Carl H., 'Monona Grove High School'. *Science Education News,* March 1969, pp. 3–4.

Four-year, concept-centered program based on the premise that all science is concerned with the nature of Matter and Energy and with the matter-energy interactions as a function of Time. The consequence of these interactions is Change which is the central theme of the program. The article goes on to outline the structure of the program. Now in its 5th year of implementation and other traditional science courses have been phased out.

Phenix, Philip H., 'The Architectonics of Knowledge'. *Education and the Structure of Knowledge,* Rand McNally, Chicago, 1964, pp. 44–62.

Paper presented at fifth annual Phi Delta Kappa Symposium on Educational Research. Categorizes human knowledge into principal groups depending on 'generic' ways of knowing. Six categories occur of which science ('empirics') is one. This group includes, 'physical sciences, life science, psychology, social sciences'. Mathematics is excluded from the science category and is placed with 'ordinary language' into a separate group' 'symbolics'. A brief argument is made for organizing education around the six generic classes.

Popper, Karl R., *Conjectures and Refutations: The Growth of Scientific Knowledge,* Harper Torchbooks, New York, 1965, p. 417.

Presents a philosophical picture of all science in which the key is certain statements that are potentially falsifiable. The better the theory is the more it prohibits and, therefore the more potentially falsifiable. Points out that confirmations or verifications for *any* theory are easy to find but that these alone indicate a pseudo-science. Since this thesis applies to all science, it is useful in developing a philosophy of unified science.

Raven, R. J., 'Toward a Philosophical Basis for Selecting Science Curriculum Content'. *Curriculum Theory Network,* Winter 1969–1970, CTN Issues 4, pp. 11–25.

Raven examines connections between various concepts used in chemistry. He discusses Margeneau's several categories of science concepts, and notes that the increasing complexity parallels to some extent the four stages of concept development in children formulated by Piaget. Scientists have to start with concrete operations and experiences as a basis for their

complex representations of nature. Margeneau's six metaphysical requirements for science concepts are also outlined; logical fertility, multiple connections, permanence and stability, extensibility, simplicity and elegance, and causality. Dr. Raven suggests that concepts chosen to form a curriculum structure should fulfill these requirements.

Ritx, William C. and Raven, Ronald J., 'Some Effects of Structural Science andVisual Perception Instruction Among Kindergarten Children'. *Journal of Research in Science Teaching,* Vol. 7, 1970, pp. 179–186.

Report of a study which examines the effects of portions of two instructional programs ('Science – A Process Approach' and 'The Frostig Program for the Development of Visual Perception') on the attainment of reading readiness, visual perceptual and science process skills in kindergarten children. Findings indicate that science can be included in kindergarten prorgams without impairing the reading readiness attainment of children and with an enhancement of visual perceptual and science process skills.

Robinson, James T., 'Science Teaching and the Nature of Science'. *Journal of Research in Science Teaching,* 1965, pp. 37–50.

Argues for a contemporary view of the nature of science distilled from the writing of many scientist-philosophers and for an increasingly important role for the nature of science in determining the school science curriculum. Distinguishes 'correlational (descriptive) and exact (predictive) sciences'. However, the former are seen as evolving toward the latter.

Robinson, James T., *The Nature of Science and Science Teaching,* Wadsworth Publishing Company, Belmont, (CA), 1968, p. 149.

Analyses the philosophical writing of several scientists: Henry Margeneau, Philipp Frank, Percy Bridgman, J. H. Woodger, Morton Beckner, and the report of a symposium on the concepts of biology. A view of the nature of the physical and biological sciences is synthesized which incorporates both inductive and deductive elements. Philosophical and methodological understandings which contribute to scientific literacy are listed.

Robinson, Lucretia G., 'Turning the Prism'. *The Science Teacher,* Vol. 40, No. 2, February 1973, pp. 48–49.

Makes a plea for developing and offering a science appreciation course in most high schools. Suggests that a knowledge of what the great men of science did would be enormously enriched by knowing something of who they were. Notes that the social sciences thrive on the outside reading techniques and the really 'concerned' young people are most often found among this group.

Rogers, Robert and Voelker, Alan, 'Programs for Improving Science Instruction in the Elementary School – Part I, ESS'. *Science and Children,* January/February 1970, pp. 35–43.

This extensive article reviews and summarizes the literature pertinent to the Elementary Science Study (ESS). More than 40 references are cited. Major sections deal with: Nature of the Program, The Development Process, Psychological Basis, Instructional Materials and Evaluation. Some of the units are certain natural phenomena as organizing themes which can serve to unify and integrate several of the specialized sciences (e.g., 'Changes', 'Small Things', and 'Mealworms'. Even though the instructional materials were developed for elementary level, many are appropriate for higher levels because they are open ended and inquiry centered.

Even though the instructional materials were developed for elementary level, many are appropriate for higher levels because they are open ended and inquiry centered.

Romey, W. D., 'Symposium: Ways to Integrate Science – Integrating Science and Social Science'. *The Science Teacher,* February 1973, pp. 28–30.

He says that the view that 'Scientists . . . should confine their attention to relatively easily isolated, simple systems where the effect of one variable on another can be shown in a convenient and reproducible fashion' is too narrow. 'Many scientists become constrained by the methods they choose to use', e.g., by standardized tests and multiple choice rather than by asking questions about attitudes and learner growth. He argues that looking at real systems in all their natural complexity with a blend of intuition and reason is what can combine physical, natural, and social sciences' 'The best school is the one most like the real world'.

Seyfert, W., 'Putting It all Together – Unified Science, A New Route to Scientific Literacy'. *Curriculum Report,* National Association of Secondary School Principals, Washington, December 1972, p. 12.

This special issue of the *Curriculum Report* is devoted to unified science education in the United States. It describes the bases on which many programs are developed. Fourteen high school programs are described briefly. The operation and services of the Center for Unified Science Education at Ohio State University are described.

Showalter, Victor, 'Unified Science': An Alternative to Tradition'. *The Science Teacher,* February 1964, pp. 24–26.

Presents a concise rationale for favoring a unified science structure for high school science over traditional course sequence. Includes a graphic theoretical model for a unified science curriculum. Describes the units that comprise the four-year unified science program at the laboratory school of The Ohio State University and current problems and future outlook of the program.

Showalter, Victor, *Effects of a Unified Science Curriculum on High School Graduates,* Ohio State University Research Foundation, Columbus, 1967, p. 105.

Specific effects of a 4-year unified science curriculum (grades 9–12) were grouped in: (1) interest in science; (2) scientific literacy; (3) preparation for college. The 358 subjects had graduated from high school one to seven years prior to study. Efforts were made to control: intelligence, school achievement, school setting, sex, age, etc. Findings indicated general and consistent favorability for unified science over traditional curriculum. Level of significance exceeded arbitrary minimum in several cases. Includes syllabus, ASLI test for scientific literacy, bibliography of unified science.

Showalter, Victor, 'Chemistry in a Unified Science Curriculum'. *School Science and Mathematics,* April 1967, pp. 334–340.

Describes how chemistry is used as an instructional vehicle in a unified science program and identifies differences and advantages of a unified science approach over traditional chemistry courses. Attempts to show that many of the major concepts dealt with in chemistry are subsumed by more general concepts that permeate all the special sciences.

Showalter, Victor, 'New Directions for Science Curriculum Development'. *ERC Papers in Science Education 2,* Educational Research Council, Cleveland, Ohio, June 1968, p. 26.

This working paper describes proposed rationale for and methods of development to be used by the Educational Research Council of America to facilitate unified science education. Describes various factors contributing to a unified view of science. Identifies signs of a trend toward unified science education. Proposes a modular structure for the ideal unified science program. Bibliography.

Showalter, Victor, 'A Model for the Structure of Science'. *ERC Papers in Science Education 10,* Educational Research Council, Cleveland, Ohio, September 1969, p. 12.

This talk was presented to the Fourth Annual Conference of the Federation for Unified Science Education (FUSE) at Monona Grove, Wisconsin. It sets forth a physical model based on the epistemology of science and is claimed to be applicable to all sciences. Basic elements of the model are: perceptions, real concepts, facts, laws, invented concepts, principles, and theories. These elements are arranged in a hierarchial structure. It is suggested that the model be used as a theoretical base for the development of unified science programs.

Showalter, Victor, 'Behavioral Objectives for Unified Science Education'. *Professional Growth for Teachers,* 1969, p. 2.

'A unified science curriculum is one in which the traditional boundaries are dissolved for instructional purposes'. Specific behavioral objectives for unified science are given under the broad headings of the student should: (1) view science as being relevant to his own life; (2) demonstrate attitudes that are consonant with science; (3) engage in the processes of science; (4) be interested in science, at least to the extent that he has no aversion for it; (5) be able to seek more knowledge in science after he leaves high school; (6) perceive the unity of science and the unique roles played by various science disciplines and know something about science on standardized tests and on understanding science.

Showalter, Victor, 'Fusing the Sciences', *Scholastic Teacher,* October 1970.

Responds to the question, 'Is there, in fact, a contemporary trend toward establishing unified science course structures?' Uses attendance at annual conferences of Federation for Unified Science Education (FUSE) as indicator of increasing interest by educationists. Identifies and gives examples of four types of organizing themes around which unified science units could be developed.

Showalter, V. M., 'Symposium: Ways to Integrate Science – The FUSE Approach'. *The Science Teacher,* February 1973, pp. 25–27.

The Federation for Unified Science Education (FUSE) was formed in 1966 and supports the idea that traditional science subjects are 'too disjointed and compartmentalized to facilitate the goals of liberal or general education'. Unified Science programs in schools are very diverse and are usually arranged around processes, concepts, problems, or natural phenomena. Some facilities of the Center for Unified Science Education are described and a nine-phase approach to developing a unified science program is outlined. A curriculum consisting of several units each with a number of modules or activities is suggested as a viable way to allow for continuous development of the program over time.

Showalter, Victor and Slesnick, Irwin, 'Program Development in Unified Science'. *The Science Teacher,* December 1961.

Proposes that the usual discipline orientation of school science courses be merged '. . . in depth by design . . .' and described the approach taken in developing a unified science course at the laboratory school of The Ohio State University. The course covers four years (grades 9–12) and is intended for all students. Acknowledges probability that '. . . more schools (will) endeavor to adjust their curricula to the natural integrality of science'.

Slawson, Wilber S., 'Bases of Science Curriculum Development in the Future'. *The Science Teacher,* March 1968, pp. 22–26.

New science curricula such as BSCS, CBA, PSSC, ESCP, etc., are built around unifying themes and if a student took all of them he should obtain a good understanding in terms of all the generalizations. As this rarely occurs, the author suggests a better approach would be to combine the curricula into an interdisciplinary or nondisciplinary science arranged around conceptual themes. The unified (integrated) science program at Dwight Morrow High School, Englewood, New Jersey (grades 9–12) is then briefly described.

Stotler, Donald W., 'Science Heuristics, and Humanism'. *The Science Teacher,* October 1965, p. 28.

Classroom learning must become increasingly self-initiated, self-paced, and self-connected. Necessary changes in environment, objectives, time allotments, freedoms and responsibilities, attitudes towards concepts and evaluation are described. Anticipated student mobility between schools would necessitate computerized information on individual learners. Proposed multipurpose community centers are also described.

Szent-Gyorgyi, Albert, 'Interdisciplinary Science Education: A Position Paper'. *The Science Teacher, Supplement,* November 1970, pp. 3–4.

A paper presented to the 1969 Conference on Interdisciplinary Science Education (L. Schubert, Director). Presents view that '. . . unification of knowledge is the greatest achievement of science and, perhaps, the greatest achievement of the human mind'. Advocates that science teaching starts with natural phenomena which is different from the abstractions peculiar to the separate sciences. Acknowledges the past necessity for studying isolated phenomena in terms of separate sciences but sees that in the present, '. . . various disciplines have already fused into one big body of knowledge, one great new central science, though as yet it has no name . . . we should avoid dismembering this unit'.

Thier, Herbert D., 'Laboratory Science for Visually Handicapped Elementary School Children'. *New Outlook for the Blind,* June 1971, pp. 190–194.

Describes the general developmental process involved in adapting unit materials from the SCIS program for visually handicapped children. Specific examples are given for an experience with fish in a first-level biological science unit and for work with solutions in a third-level SCIS physical science unit.

Thompson, Peter, 'High School Biophysics'. *The Physics Teacher,* October 1967, pp. 322–325.

Describes a course at twelfth grade level which was developed in response to '. . . the danger that the rigid formalism separating biology, chemistry, and physics can lead to false distinctions

in the student's mind . . .' without dealing with problems too complex for treatment at this level. The combination of biology and physics can generate 'creative thought' and lend '. . . interest and diversity to the class discussion'. Gives examples of biological phenomena under headings as: scaling, light, sound, mechanics, heat, electricity.

Thomson, Barbara and Voelker, Alan, 'Programs for Improving Science Instruction in the Elementary School – Part II, SCIS'. *Science and Children,* May 1970, pp. 29–36.

This extensive article is a summary review of literature relating to the Science Curriculum Improvement Study (SCIS) which directed its efforts to grades K-6. Major sections of the article deal with: 'Nature of the Program', 'Psychological Bases', 'The Learning Environment', 'Instructional Materials', and 'Evaluation'. The latter includes studies by persons not connected directly with the project. A total of 32 references are cited.

The program aims to '. . . integrate the life sciences, the physical sciences, and quantitative comparisons'. Organizing themes for units are big ideas that permeate all science such as: 'Sub-systems and Variables', 'Periodic Motion', etc.

Troost, Cornelius, 'A Critique of Unified Science'. *School Science and Mathematics,* December 1968, pp. 845–846.

The author acknowledges the growing interest in unified science education and identifies 'two primary objectives of unified science: (1) scientific literacy, and (2) development of a rational, integrated view of the universe'. Expresses belief that these are too vague and ambiguous although the second 'is amenable to translation into behavioral terms'. Identifies 'another serious problem confronting the teachers of unified science (as) the religious backgrounds of their students'.

VanDeventer, W. C., 'An Inquiry Approach to Interdisciplinary Seventh Grade Science'. *Journal of Research in Science Teaching,* 1968, pp. 363–384.

Describes several aspects of the results of the Michigan Science Curriculum Committee project for development and testing of curriculum materials for the junior high school. Takes a '. . . revitalized general science approach . . . in terms of problems, ideas, and understandings, rather than a limited factual survey of conventional science fields'. The content of the materials is based on selected '. . . ideas or understandings that cut across two or more fields of science . . .'. Identifies thirteen 'cross-cutting' ideas as 'gradients, cycles, and dynamic equilibrium'.

Walker, Marshall, *The Nature of Scientific Thought,* Prentice-Hall, New York, 1963, p. 184.

'. . . addressed to those who wish to learn the basic purpose and procedure common to all the sciences'. '(It) describes a unified approach to all branches of science, and the author must be permitted considerable liberty in the generalization of some concepts and the oversimplification of others if such unity is to be achieved'. 'The statements in this book concerning science, mathematics, and philosophy are believed to represent the consensus of scientists'.

Ward, Robert W. and Reynolds, G. W., and Nurnberger, R., 'Unified Science: A Workable Approach'. *Science Education,* March 1969, p. 137.

Describes a college course intended 'to enhance the overall understanding of the nature of science for students not majoring in science'. The course extends through two semesters and develops five 'unifying themes for science'. Among these themes are: 'Changes in structural organization are accompanied by energy changes' and 'Systems evolve'. Reports that 60% of the first student group felt that the course involved 'fundamental ideas and concepts which related large blocks of knowledge in science'.

Watson, F. G., 'Teaching Science to the Average Pupil'. *The Science Teacher*, October 1966.

Historically, we have neglected the average pupil, centering more for the science-orientated student. The author outlines a nationwide center for science curriculum development that would produce units directed toward different kinds of students The schools could use these tested materials to create their own patterns of scope and sequence. A 'program centered' curriculum is recommended with a consequent shift in the teacher role toward guide and counsellor. Such development would offer greater opportunities for individualizing instruction.

West, Roland, 'Merger of Social Studies and Science in Sixth Grade'. *The Elementary School Journal*, May 1958, pp. 445–448.

Gives examples of consolidation of subjects and then explains the rationale and procedure behind merging social studies and science. The author lists topics usually covered separately in sixth grade and out-lines five units that he wrote to bring these topics together. Some units are 'Our world and beyond', 'Man and his food', and 'Communications, today and yesterday'; each is scheduled to take about eight school weeks.

Winthrop, Henry, 'Interdisciplinary Developments in Undergraduate Education'. *Science Education'*, December 1965, pp. 410–419.

Identifies a problem in 'interdisciplinary developments and curriculum lag'. Uses 'interdisciplinary developments' as new areas of empirical nature and/or theoretical nature which have significance for and application in many sciences including the social sciences. Cites 'information theory' and 'input-output analysis' as two of these developments and shows how a minimum of mathematical knowledge will enable these areas to become part of the undergraduate curriculum for many if not all students.

Young, J. A., 'Restructuring Chemistry Curricula'. *Journal of Chemical Education*, October 1967, p. 564.

An understanding of chemistry is no longer best obtained by dividing this subject into the traditional branches of organic, inorganic, analytical, and physical chemistry. Similar questions are asked within each division and many areas such as polymer chemistry and colloid chemistry cannot be fitted into any of these traditional divisions. There is a need to find answers to the question 'What is the structure of chemistry?' and to develop new curricula.

Young, J. Z., *Doubt and Certainity in Science*, Galaxy Books, Oxford University Press, 1960, p. 168.

Based on BBC lectures of 1950. Details in popular language, the present status, methods, and frontiers of research dealing with the brain. Concludes with a chapter on the nature of science including its evolution which leads to '. . . less sharp separation between physical, biological, and sociological science . . .'. 'The aim of the new unified science (will) be to define those relations between population of people enabling them to communicate information and so to maintain life. This is the way of speaking that can unify all our scientific activities'.

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